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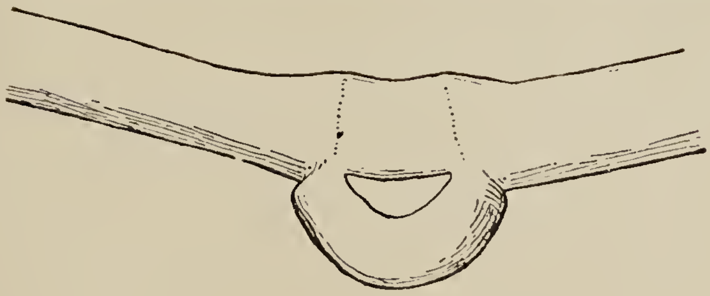

Fig. 1. × 3.

Through inadvertence the above Figure was printed upside down on p. 134 (June issue) of Vol. II. of this journal. The present Figure, correctly printed, is intended to be cut off and pasted over the old one.

THE

NEW PHYTOLOGIST

A BRITISH BOTANICAL JOURNAL,

EDITED BY A. G. TANSLEY, M.A., F.L.S.,

ASSISTANT PROFESSOR OF BOTANY IN UNIVERSITY COLLEGE, LONDON.

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THE

NEW PHYTOLOGIST.

Vol. I., No. I. January, 23rd, 1902.

EDITORIAL.

WHEN the notion of starting a new botanical journal in this country was first mooted some months ago, we were plainly told by a certain distinguished botanist that it was not enough to shew there was room for a new periodical, an actual necessity for its existence must be established. But it may, we think, at least be contended that there is another point of view. Nature does not go about painfully to prove that the existence of a new organism is absolutely indispensable—she throws it upon the world and leaves it to take its chance. If there is room for the new-comer, if it is well adapted to fill its place in the scheme of things, it survives. If not, it inevitably goes under and disappears. And the same considerations apply in the main to the appearance of a new journal. The struggle for life will not spare it, and if it maintains its place it establishes its right to exist. It is true that under the conditions of civilization certain undesirable types of organism continue to live, protected by an artificial environment. A parallel may be found in the kindly but mistaken "loyalty" which prompts some people to support a magazine which they do not want, or which has outlived its claims to recognition. We do not seek such help at the outset of our adventure, nor do we expect to keep the support of our present subscribers if the new journal fails to provide them with anything they care to have. Meanwhile the experiment seems worth making.

The main idea which led to the inception of the present journal is easily set down. It seemed that there was room for a medium of easy communication and discussion between British botanists on all subjects connected with their branch of science, methods of teaching and research as well as purely scientific questions. Topics are constantly arising on which such discussion would be valuable not only to the one or two people immediately interested, but to the rest of their colleagues.

At the same time the possibility of readily publishing observations or views which would probably never be worked up into an elaborate paper suitable for publication through one of the regular channels at present existing, would often be of use both to the author and to his fellow workers. It must be within the experience of most of us that observations are constantly being made and views suggested, which at present never see the light because their authors are engaged on other work, and lack the time or perhaps the inclination to follow them up. Meanwhile they might afford a much needed help or clue to some other investigators. It is not intended to make this journal specially the medium of that often abused form of publication the "preliminary note." We quite agree with the opinion which is frequently expressed, that this type of production is rather overdone in the existing periodicals. On the other hand there are special cases in which it is desirable, and authors may find the new journal a convenient medium for announcing discoveries or theories which seem to call for immediate publication. In other cases papers which may be considered unsuitable for any of the existing journals will here find an appropriate home.

Short notices of important new books and papers will also, we hope, be a regular feature of our pages. Such notices (which need not necessarily be exhaustive reviews) are easily enough written by those *au courant* with special branches of the science, and would often be of very widespread interest.

It soon became clear that if a journal devoted to the objects sketched above were successfully started, it would appeal to another class besides that of the working botanist and original investigator. There is a considerable number of persons in this country keenly interested in the progress of botany, but cut off from contact with the centres of botanical activity. Many of them are teachers in secondary schools, and others are amateurs, whom circumstances prevent from actively following their favourite study. The response which the preliminary circular met with from this class leaves no doubt that such a journal would be warmly appreciated in these quarters. Our columns will always be open to enquiries for special information or statements of difficulties on topics theoretical or practical from readers who may be in want of help, and we have no doubt a ready response will be forthcoming from others who are in a position to be of use.

Such are the main objects we have in view in founding the New Phytologist, and we venture to believe that with the cordial co-operation of our readers, we ought to succeed in carrying them out. It will, however, be clear from what has been said, that without this co-operation there is no prospect of success. Our pages must be largely filled with correspondence, notes and short reviews, and without a liberal supply of material from our readers we cannot hope to carry on a magazine conducted on these lines. But we trust that if the objects we have in view seem fairly in the way of realization, there will be no lack of such supplies. The conditions applying to contributions intended for publication will be found fully stated on the inside of the back cover.

We feel that some apology is due to our subscribers for the comparatively small number of pages we are at present able to produce. Prudence dictated a modest beginning, but we hope that the number of our subscribers and the amount of available matter will soon justify an enlargement.

The New Phytologist is not intended to be the rival of any existing periodical. To some extent of course our work must overlap that of others, but we believe that in the main we shall fill a place which is at present vacant.

REVIEW.

CELAKOVSKY on "THE SEGMENTATION OF THE STEM."

ARE we justified in saying that our doctrines of the general morphological construction of the axis of the higher plant are essentially correct? According to Professor L. Celakovsky, of Prague, who writes in the *Botanische Zeitung*, Heft V./VI. of last year, under the title of "Die Gliederung des Cauloms," our writers of text-books and botanical authors generally are largely in the dark as to the real facts connected with the building-up of the stem.

After referring in his introductory remarks to the orthodox views on the structure of the stem as found in the text-books of St. Hilaire and Schleiden, he opens his first chapter, entitled "The Articulation of the Stem in General," with a consideration of those axes possessing amplexicaul leaves; such he terms *holocyclic* stems, and regards them as being constituted of a series of "stem-joints" (Stengelglieder) placed one above the other, each occupying the entire diameter of the axis and terminating at the node in a leaf. As each leaf arises from that portion of the apex which becomes the stem joint to which it belongs, we may regard, he says, the leaf along with the lattter as a morphological unity, and term it a *Sprossglied* (shoot-segment). The entire monocotyledonous embryo (apart from the root) represents a first such "Sprossglied," the hypocotyl being its holocyclic "Stengelglied." Holocyclic articulation is characteristic of monocotyledons.

The second type of stem-articulation is that called *mericyclic*, in which each of the stem-joints occupies a portion only of the whole diameter of the stem, as in the case of spirally-arranged leaves. In a stem with $\frac{1}{3}$ phyllotaxy the three "Sprossglieder" are united in the centre of the axis as three wedge-shaped portions instead of each occupying the whole diameter as in a holocyclic stem. Mistaken ideas have always been entertained as to what constitutes the *internodes* in such stems: usually the internode has been held to be that portion of the stem intervening between any two leaves, but this, according to the "Sprossglied" theory, is absurd, the true internode necessarily lying *between two superposed leaves*. In stems with whorled leaves the internodes consist of serial stem-joints grouped at the same level. Thus in mericyclic articulation the Sprossglieder are *juxtaposed*, in holocyclic, *superposed*.

Chapter II. is devoted to the origin of the stem with holocyclic "Sprossglieder." After citing various authors, including Delpino in his work on Phyllotaxy, who have intuitively held the "Sprossglied" theory, he refers to the two categories of independently developed "Sprossglieder," *viz.* (1) an axillary shoot reduced to the first "Sprossglied" (*i.e.* a leaf with its stem-joint) as in the male flower of *Lemna*, *Zannichellia*, *Najas*, *Casuarina*, in which the stem-joint is indistinguishable from the filament; in the female flower of *Balanophora*, *Araucaria*, Podocarpeæ, *Ginkgo*, *Typha*; and in the vegetative shoot of *Lemna*: (2) the "Sprossglieder" of a sympodium where each ends in a terminal leaf, an analogy with which is found in the sympodia of *Ampelopsis*, the inflorescence of Boraginaceæ, etc.

In the monocotyledonous embryo, as Hanstein has shewn, the cotyledon is a leaf *terminal* to the hypocotyl, hence Nägeli, Sachs, and Leitgeb were led to regard the whole embryo as a thallus. E. Fleischer and F. Hegelmaier (in work which has been ignored by our text-books) shewed that the second phase in the development of the embryo consisted in the development at the base of the cotyledon of a protuberance whose upper part became a terminal leaf and its base a "Stengelglied," out of which arises the next protuberance; 'the stem is built up of a succession of generations of independent "Stengelglieder" springing laterally from an antecedent "Stengelglied," in fact a sympodium of "Sprossglieder,"' until eventually an apical growing point is formed. Previous to the formation of this latter an axis is not present, so that Al. Braun erred in stating that the theory of phyllotaxis demands the presence of a stem as a basis on which the leaves may arise, as also did Sachs and others in holding the view that leaves *always* arise laterally on a previously-formed axis.

Comparative development unequivocally shews, according to Celakovsky, that the monocotyledonous embryo is a *vegetative transformation* of the Bryophytic sporogonium, and each "Sprossglied" is a repetition of this latter. The incipient stages in the branching of the monocotyledonous embryo the author terms *pleuroblastic*, its subsequent branching and the growth of the higher plants generally, he terms *acroblastic*, these two, *i.e.* the formation of an embryonic shoot by means of a succession of "Sprossglieder," and that by means of a vegetative growing point producing lateral leaves, can only be modifications of the same mode of development, and cannot be due to different morphological qualities of the same embryonic shoot. In *acroblastic* branching the leaves, although they form the organic terminal portions of each "Sprossglied," arise laterally on the plant because they are *retarded* in their development› not growing out until after a second "Sprossglied" does so; this latter being much stronger than the leaf of the last "Sprossglied" immediately behind it, necessarily overtops that leaf and becomes terminal. Acroblastic is more rapid and stronger than pleuroblastic branching and hence has been adopted in almost all plants; the former has been derived from the latter. *Dichoblastic* branching is intermediate between acro- and pleuroblastic, and possibly preceded the former; it apparently occurs in the early development of the embryo of Pteridophytes.

In Chapter III. the origin of stems with mericyclic "Sprossglieder" is considered. Here it is shewn (and this can only be clearly understood, perhaps, by reference to the diagram given) that an acroblastic stem with mericyclic "Sprossglieder" can be derived from a pleuroblastic one by vertical *fusion* of the holocyclic "Sprossglieder" of the latter above and below, and this fusion occurs *congenitally* in every stem; this is seen in the mosses. The protomena of a moss possesses holocyclic "Sprossglieder;" in the moss-plant the latter are mericyclic where each segment cut off from the apical cell does not extend entirely across the stem, but abuts on the wall of the last segment. The apical cell of a cryptogam corresponds with the formation of the three wedge-shaped segments of the mericyclic "Sprossglieder" of a plant with $\frac{1}{3}$ phyllotaxis. An apical meristem, which as in the Fern, cuts off a number of segments from the apical cell before the first leaf is formed, as also the *layered* apical meristem of Phanerogams consist of more than one "Sprossglied"; the apical cell has given rise to the layered condition by means of early divisions in its segments, so that the "Sprossglieder" have become quite obscured, but are nevertheless present. Hence the origin of mericyclic stems from holocyclic, which is distinctly perceived in the mosses and Pteridophytes, has become obscured (by further complications connected with cell-division) in the Phanerogams.

Chapter IV. contains a setting-forth of all the numerous advantages of the "Sprossglied" doctrine and is a most ingenious exposition and explanation of several very important facts connected with the articulation of the stem.

In the final chapter we are made acquainted with the part played by the "Sprossglied" in the theory of the *plant-individual* and in *phyllotaxis.* In this it is shewn that the "Sprossglied" is the simplest morphological "individual," since the "shoot," the entire plant itself, and the cell, all lack certain qualities which are necessary in order to qualify for that distinction. Hence Al. Braun was in error in regarding the "shoot" as the true "individual." As regards Phyllotaxy the "Sprossglied" theory shews that the arrangement of leaves on the stem has not been brought about by shifting and displacement of the leaves so as to suit space-adjustment on an elongating cylindrical structure, the stem, which latter was wrongly regarded as a simple unity in itself bearing the leaves as mere lateral "appendages," as by Hofmeister, Sachs, and Schwendener, but as Schumann and Jost have lately shewn, the positions of the leaves on the stem, as must necessarily result from the fact of the latter being built up of "Sprossglieder" (leaves, each with its corresponding "Stengelglied"), are fixed and invariable from the first.

Finally, the author wishes to impress his readers with the fact that the "Sprossglied" doctrine is a necessary consequence of well-ascertained facts, of which the development of the monocotyledonous embryo takes the first rank. The mericyclic stems of Phanerogames with their layered apex stand in a more hypothetical light, but "a hypothesis which, by means of logical reasoning, can be deduced from well-ascertained facts, will everywhere be regarded, as in physics, as the more impregnable and credible the more facts which are obscure eventually become placed by it in a clear light, and by doing this it affords compensation to the understanding for what is lacking in direct evidence appealing to the senses."

The reviewer feels that he cannot too strongly insist upon the value attaching to this latest contribution by our author, the more so as the productions of the latter, unrivalled as he probably is in knowledge of, and power of rightly interpreting facts relating to the morphology of the higher plants, appear, for some strange reason, to be seriously under-estimated or neglected.

A plate of most lucid and instructive diagrams accompanies the letterpress of the paper. W. C. W.

NOTES ON CURRENT LITERATURE.

THE PROTEOLYTIC FERMENT OF NEPENTHES.

IN the December number of the "Annals of Botany," Professor Vines of Oxford criticises Clautriau's work on the proteolytic ferment of the pitchers of *Nepenthes*, and restates his previous conclusion that the enzyme in question (Nepenthin) is tryptic rather than peptic in nature though it differs from trypsin in being active only in an acid medium, and apparently also in forming less leucin and tyrosin (which have not indeed been demonstrated at all).

The ferments of the Papaw and the Pine Apple are intermediate in character between nepenthin and trypsin in both these respects, *i.e.*, they are most active in *neutral* media and produce demonstrable leucin and tyrosin, though less than does trypsin. Professor Vines concludes with the interesting suggestion that tryptic digestion (which occurs alone in many invertebrates and is the only demonstrated proteolytic process in plants) is a property of all living organisms and the more primitive form of the digestive process.

ANATOMY OF GLEICHENIACEÆ.

In the same number of the "Annals" Mr. Boodle concludes his account of the comparative anatomy of the Hymenophyllaceæ, Schizæaceæ and Gleicheniaceæ with a paper on the last-named family. The most interesting new fact is the discovery that one species (*G. pectinata*) is solenostelic, *i.e.* monostelic with a hollow cylinder of xylem clothed within and without by phloem, pericycle and endodermis, and enclosing a central pith. This affords clinching proof, if such is still needed, that this type of structure, which was called by Van Tieghem "gamostelic" and supposed to be derived from the "dialystelic" condition characteristic of the higher Leptosporangiate Ferns by lateral fusion of the separate "steles," is (in this case at least) to be derived from the protostelic condition (monostelic with solid central xylem surrounded by phloem, pericycle and endodermis), which is almost certainly primitive in *Gleichenia*, by the development of internal phloem, etc. and central pith.

The various other interesting points which Mr. Boodle works out, particularly the facts connected with the curious "nodal islands" of sclerenchyma and phloem first described by Poirault in 1893, cannot be discussed here, but it may be said that they contribute in an important degree to the general theory of the evolution of the vascular system of Ferns which we shall very soon be in a position to formulate.

STARCH-FORMATION IN HYDRODICTYON.

Mr. Timberlake of Wisconsin University contributes to the same periodical an important paper on Starch-Formation in *Hydrodictyon.*

Mr. Timberlake finds in the first place that the whole of the cytoplasm, with the exception of the ectoplasm and vacuole-wall, contains chlorophyll, so that in *Hydrodictyon* there is no specially differentiated chromatophore.

By the application of modern cytological technique he has succeeded in shewing that the distinction drawn by Klebs between pyrenoid-starch (formed immediately around the pyrenoids) and stroma-starch (formed in the substance of the chromatophore without relation to the pyrenoids) is illusory, and that the whole of the starch found in the *Hydrodictyon*-cell is derived from the pyrenoids. Actual pieces of these are cut off, changed into starch, and pushed out into the surrounding cytoplasm, where their arrangement and shape often clearly indicate their origin. The author is of opinion that the pyrenoid is "an active body, differentiated in the chlorophyll-bearing cytoplasm, which in cooperation with the latter acts as the base of the process of starch-formation." How far these conclusions can be extended to all algal cells possessing pyrenoids, and what is the significance of the apparently fundamental difference between this method of starch formation and that obtaining in the plastids of the higher plants, must remain at present open questions.

[We hope to make the "Notes on Current Literature" much more extensive in succeeding numbers.]

MISCELLANEOUS NOTES.

The Old and the New "Phytologist."

In reviving the name "Phytologist" in the title of the present journal, we naturally look back at the magazine which bore it from 1842 to 1863, at first under the management of Edward Newman and the editorship of George Luxford, and later on, after the death of the latter, under the editorship of Alexander Irvine. Edward Newman's Preface to the first volume begins as follows—"The Phytologist owes its existence to the desire of recording and preserving facts, observations and opinions relating to Botany in general, but more especially to British Botany. Prior to its commencement *these* had no appropriate receptacle."

With certain qualifications these words would form no bad preface to our own venture, Enormously as the study of botany has increased and advanced in this country since 1842, and greatly as facilities for publication have multiplied, there seems now as there seemed sixty years ago "no appropriate receptacle" for a whole class of "facts, observations and opinions" which we cannot but believe would be useful and advantageous to publish.

It is true that in many respects the present journal will differ much from the old "Phytologist." We do not propose to devote our pages mainly to British Botany. There is already in existence a journal which well fulfills the function of publishing new facts and critical notes about the native flora. Nevertheless we shall always cordially welcome any contributions on this subject provided they have a certain general bearing. Our pages indeed will be mainly filled with topics differing so widely from those discussed in the old "Phytologist," that a casual inspection of the two journals by an inhabitant of Mars would hardly reveal that they were dealing with the same branch of science. This is one of the effects of the botanical activity of the last sixty years. But if we can in any degree fill our place as worthily as the old "Phytologist" filled its place, if we can even approach to giving our readers the pleasure and profit that they must have derived from its delightful pages, we shall be more than satisfied.

THE PROBLEM OF REFERENCE IN SCIENTIFIC LITERATURE.

The opening years of the present century are witnessing the progress of several attempts to deal with the ever increasing difficulty of reference to published work in science. The Royal Society International Catalogue has now made considerable progress, and the beginning of the present year sees an important advance in this direction so far as botanical literature is concerned, the taking over of the well-known *Botanisches Centralblatt* by the "Association Internationale des Botanistes," founded last August at Geneva. Applications for membership of the association should be made to Dr. J. P. Lotsy, Oude Rijn 33a, Leiden, Holland, who is Editor-in-chief of the new *Centralblatt.* Members will pay 25/- per annum and receive the jonrnal post-free. The latter has been organized on business-like lines, staffs of specialist editors for the different branches of the science having been appointed in the various countries. The re-organized *Centralblatt*, which is to contain abstracts of all important botanical publications and very full lists of current literature, should be invaluable to every working botanist.

The first number (January 3rd) which has just reached us, shows that the old form of the *Centralblatt* has been kept in practically every detail, the printer indeed being the same as before, while the new publisher is Brill, of Leiden. There is an interesting account, by Dr. Lotsy, the secretary and principal editor, of the origin of the "Association Internationale," from which it appears that schemes for originating a really efficient general botanical reference-organ originated separately in Europe and America, and it was by the co-operation of their promoters that the present organization took practical shape. There is also a list of the specia editors for the different countries and a complete list of members of the "Association," from which the geographically very widespread support of the scheme is obvious. We regret to see however that the British Isles are responsible for only 29 members as against 84 in the United States, 56 in Germany and 49 in France. We hope that some of our readers may help to bring the British membership up to a more respectable figure. Of the value of the undertaking and the duty of all botanists to support it there can be no doubt.

The *Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten* has also been reorganized, and is to appear in an enlarged form. Part II., which will deal with the botanical and technical, as opposed to the medical and hygienic, side of the subject, is under the joint editorship of Dr. Uhlworm (late of the *Botanisches Centralblatt*) of Berlin, and Dr. Hansen of Copenhagen, and will publish original papers, reports of societies and institutions, and reviews, contributors being remunerated at fixed rates. It is to be hoped that an effort will be made to notice all bacteriological publications which do not appear in its own pages. The rigid specialization of scientific journals is in these days a most desirable direction in which to aim, and we should like to see it carried very much further than has been attempted at present.

THE "SEMINAR" METHOD IN BOTANICAL TEACHING.

We are very glad to be able to publish Mr. Seward's interesting account of his experiment in the co-operative method of advanced teaching familiar at German Universities in the various "seminars." We do not think that (with the exception of Professor Miall's classes, which we gather were elementary) it has been previously tried in this country in any of our University departments of Botany, but we believe its obvious merits will quickly recommend it to many of our botanical teachers, now that Professor Miall's and Mr. Seward's evident success are on record. It will we believe be found to be readily applicable to many of the branches of botany commonly taught in our Universities, physiology, anatomy and ecology being those perhaps which most readily suggest themselves as suitable for the experiment. One great advantage, we think, will be the absolute impossibility of either teachers or students using it for purposes of "cram." We shall be glad to publish correspondence on the subject from botanical teachers.

THE SEGMENTATION OF THE STEM.

In connexion with the review which we publish of Professor Celakovsky's work on the segmentation of the stem, it may be of interest to point out the striking similarity of some essential points in his theory with the hypothetical account of the evolution of the shoots of Angiosperms given by Mr. Herbert Spencer in his

Principles of Biology (Revised Edition, Vol. II., pp. 50-80). Mr. Spencer derives the shoot-system of the Angiosperms from a sympodium of frondose (thalloid) shoots such as is often formed in the frondose Liverworts. He then endeavours to trace in the monocotyledonous and dicotyledonous types the necessary outcome of two different lines of adaptation to the vertical habit. Into the details of his theory, many of which differ entirely from those of Professor Celakovsky's, we cannot of course enter here, but a fundamental agreement consists in regarding the leaf plus the stem joint ("Sprossglied" of Celakovsky) as the unit of shoot construction, and hence in taking Celakovsky's pleuroblastic type as primitive. Mr. Spencer's derivation of the acroblastic method of growth by crowding and dwarfing of the successively formed leaf-rudiments (Figs. 100-104, p. 65) is also essentially in accord with the views of the Bohemian morphologist.

HERBARIUM SPECIMENS FOR TEACHING PURPOSES.

We have received from Mr. M. Buysman of Middleburg, Holland, some very admirable dried specimens of plants, both native and exotic. The complete specimens are very well arranged and displayed, but the special feature of Mr. Buysman's series is the means taken to preserve and display the various morphological characters of the species that can be revealed by ordinary dissection and with the aid of a lens. The perishable parts of the flower or fruit are dissected and preserved in a small flat bottle of spirit which is placed in an envelope attached to the sheet, while the dry parts such as the seeds or achenes are put into another envelope. In this way all the characters necessary for the diagnosis of the species can be made accessible on the herbarium sheet. For detailed treatment of a genus or small family, where fresh material is not available, this "Herbarium analyticum" should be of very great use to teachers. The price of each sheet is one shilling. Mr. Buysman is willing, we understand, to prepare any accessible species, not in his list, to order.

CORRESPONDENCE.

To the Editor of the NEW PHYTOLOGIST.

SIR,

I shall be very much obliged if any of your readers can give me information as to the best methods of staining and permanently mounting unicellular organisms as microscopic preparations. Having to deal with these minute organisms (e.g.: the Protococcoideæ), in the course of my teaching work I find considerable difficulty in illustrating those points of structure which cannot be observed on living material, and in making permanent preparations of forms not easily obtainable at will. I want hints as to methods of dealing with such forms satisfactorily, not involving too elaborate or difficult technique, from someone who is more experienced than myself in such work.

I am, Sir,
Yours, etc.,
A TEACHER.

Dec. 20th, 1901.

NOTE ON BOTANICAL TEACHING IN UNIVERSITY CLASSES,

By A. C. SEWARD, F.R.S.,
University Lecturer in Botany, Cambridge.

AT the Glasgow meeting of the British Association in September, 1901, the Botanical and Educational sections held a joint discussion on the teaching of Botany. One of the most valuable contributions on the subject of University Teaching was made by Professor Miall[1] of the Yorkshire College, Leeds, who gave an account of the methods which he adopts in an elementary course in Biology. Professor Miall expressed himself in favour of Laboratory practice as the most important part of teaching, and stated that his preference for this side of the work had led him to give up the formal lecture and to adopt a system very different from that usually followed by University teachers. The students begin their work in the laboratory, where they receive such assistance from demonstrators as enables them to employ the best practical methods; an adjournment is then made to the lecture-room, and a few of the students are called upon to give an account of their observations in the laboratory. Whereas in most courses, the lecture usually precedes the practical work, in

[1] "Nature," Oct. 10, 1901. p. 593.

Professor Miall's system it is superseded by short accounts given by the students themselves at the end of the laboratory work, which are based upon their own observations.

The object of this note is to give a short sketch of a method which I have adopted during the past term in an advanced class attended by seven men and two women. During the last three years I arranged the practical work in courses on Anatomy, Gymnosperms and Pteridophytes, so that each member of the class undertook a separate piece of investigation, instead of working through a common syllabus. The practice has been for each individual to prepare a series of sections or other preparations illustrating definite structures, and then to write a concise account of the work, illustrated by sketches explanatory of the preparations; the sections and descriptive notes being eventually examined by the other members of the class. This method worked fairly well, but was not entirely satisfactory. Since learning more of Professor Miall's system I have modified my plan, and as the experiment has been, on the whole, successful, I venture to describe in outline what we have done during the term, in the hope that suggestions may be received from fellow-teachers which will enable me to introduce improvements.

The course was on the Pteridophyta, which were treated both morphologically and from a systematic standpoint. Fresh material from the Botanic Garden, supplemented by Herbarium sheets, was used in illustration of family and generic diagnostic characters, and for the purpose of demonstrating features of morphological and biological interest. Each student was expected to examine all the specimens and to make drawings of important external features; the anatomical work, on the other hand, was shared among the members of the class and dealt with in a manner which may be best described by means of a few examples of the actual investigations undertaken by different students. The practical work was preceded by an hour's lecture, but plants were often examined in the laboratory before they had been described in the lecture-room.

A. spent several days in investigating the morphology of complete specimens of *Botrychium Lunaria*; the best sections were fully labelled and placed in a tray which was accessible to the other students. On the completion of the work A. gave a short account (twenty minutes) of his results, illustrating the main points by black-board sketches; this included a description of the anatomy of the stem, leaf and root, the arrangement of the young leaves at the apex of the stem, the manner of exit of the leaf-traces and roots, with notes on other characters of morphological interest. Demonstration sections of *Helminthostachys, Botrychium Virginianum* and other species were also circulated as additional examples of the Ophioglossaceæ. B. and C. undertook an anatomical investigation of *Dennstædtia apiifolia* (=*Dicksonia apiifolia* Sw. of Hooker and Baker), a fern which differs in the tubular form of the stele and in certain soral characters from the typical Cyatheaceae. The account of this work included a description of the anatomical structure of the stem,—the position of the protoxylem elements being determined by sections cut near the apex,—also an account of the origin of the leaf-traces and roots and the structure of the sori and sporangia. A complete plant of *Trichomanes reniforme* was given to D., who gave a brief account of the morphology of the species, and compared the anatomical characters with those of other members of the same family as described in Mr. Boodle's recent paper on the Hymenophyllaceæ.[1] Another species of the same genus (*T. radicans*), chosen on account of its axillary buds, was similarly treated by E. The investigation of the development and nature of the absciss-layer in the petiole of a species of *Oleandra* was undertaken by F., and a comparative examination of the leaves of several ferns selected from the point of view of biological interest (e.g.: *Drymoglossum*, &c.) was carried out by the same student. B. and C. also examined the structure of the stem and the two kinds of leaves,—bracket-leaves and foliage-leaves,—of *Drynaria quercifolia*, special attention being paid to an inquiry into the structure and probable function of the peculiar scales, which form a dense covering over the fleshy rhizome. A comparative account of the structure of fern roots was given by G., while H. dealt with the anatomy of a species of *Gleichenia* on the lines of Poirault's work.[2] D. also made preparations of such fern prothalli as could be obtained from the Garden, including prothalli of *Ceratopteris* grown under water and on a damp surface, and eventually gave a description of the structure of the sexual organs as shown in the series of specimens.

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[1] "Annals of Botany," VOL. xiv., p. 455, 1900.

[2] Ann. Sci. Nat. (Bot.) [8], VOL. xviii, 1894.

As the laboratory work was often in advance of the lectures, references were usually given to a few papers which were likely to prove useful in the course of the investigations.

The above examples may suffice to illustrate the character and scope of the various problems allotted to or chosen by the students. The advantages of this method over that which I have previously employed were apparent in the much keener interest which was taken in the laboratory work; the members of the class were in fact engaged in original research, and their attitude was that of investigators who have problems to solve which require thoughtful treatment and careful technique. They entered fully into the spirit of the work and were stimulated to do their best, partly by the interest which they derived from the work itself and partly from the knowledge that they would be expected to give a clear account of their results to the rest of the class, who were encouraged to ask questions and offer criticisms during the short and informal lecture which the students gave on the completion of each piece of work.

The practice in speaking and presenting facts, the introduction to the methods of research and the stimulus given by the feeling of rivalry were, I consider, the most striking advantages of the system.

A REVISION OF THE CLASSIFICATION OF THE GREEN ALGÆ

BY

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AND

A. G. TANSLEY,

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THE very great advances that have been made within the last fifteen years in our knowledge of the structure and relationships of the Green Algæ, especially the lower forms, have necessitated constant revisions of their classification. There is not in English any systematic treatment of the affinities of these forms at all in accordance with the present state of knowledge, and we do not think that any entirely satisfactory scheme of the kind exists at all. Wille's treatment of the Chlorophyceæ (1890) in Engler and Prantl's *Pflanzenfamilien* contained the first systematic expression of many of the ideas that govern the modern views of the subject, but in many important respects it is now out of date, and the second edition of Engler's *Syllabus* (1898) does not depart from the lines laid down by Wille. The clearest demonstration of the inadequacy of the current system comes from the Swedish algologists Bohlin[1] (1897 and 1901) and Luther[2] (1899). Some account of their work has recently been given by one of us[3] elsewhere, but we are of opinion that the results in question are sufficiently well established to be incorporated in the classificatory system in general use.

As it falls to our lot to deliver the advanced courses of lectures on this subject at Cambridge and University College, London, respectively, we determined to draw up conjointly a scheme of classification of the plants in question so as to obtain uniformity in our treatment of the subject, and it occurred to us that such a scheme would probably be useful to other teachers.

Our diagnoses of the various larger groups have been made fuller than is usual, with the object of bringing clearly into view the relationships of the more important morphological facts, and we have added supplementary notes on specially significant points. Diagnoses of the leading genera only have been given, and some of the less important ones have been omitted altogether.

The most striking change we have made in Wille's classification is the adoption of the series of Heterokontæ[4] established by Luther (1899). The forms included in this well-characterised series are partly newly discovered and have partly been taken from the old groups of Protococcoideæ, Siphoneæ, and Confervoideæ.

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[1] Bohlin Studier öfver några slägten af alggruppen Confervales Borzi. *Bihang till K. Svenska vet.-akad Handlingar. Bd.* 23. *Afd.* 3, 1897. Utkast till de gröna algernas och arkegoniaternas fylogeni. Upsala, 1901.

[2] Luther. Ueber *Chlorosaccus* eine neue Gattung der Süsswassalgen nebst einigen Bemerkungen zur Systematik verwandter Algen. *Bihang till K. Svenska vet.-akad Handlingar. Bd.* 24. *Afd.* 3, 1899.

[3] F. F. Blackman. The Primitive Algæ and the Flagellata, *Annals of Botany*. xiv., Dec., 1900.

[4] See Blackman (1900).

This removal resulted in making the limits and arrangement of the two former groups more natural, but the Confervoideæ still remained a largely artificial assemblage. Bohlin (1901), in a striking paper on the phylogeny of the Green Algæ and Archegoniatæ, has made several further important changes in the position of genera. Many of these are so much in accordance with the trend of our own views that we have not hesitated to adopt them. We have for instance taken the opportunity to break up the group of Confervoideæ altogether, and, with Bohlin (1901), to institute a series, the Ulotrichales, including only those members of the old Confervoid group which seem to belong naturally together. We have departed however from Bohlin's classification by separating the Ulvaceæ (the apparent connexion of which with Ulotrichaceæ we do not believe to be a real affinity) as a distinct series the Ulvales. Bohlin has also proposed to make the genus *Microspora*, previously included in Ulotrichaceæ, the type of a separate series of Chlorophyceæ—the Microsporales—on account of its aberrant characters. We are not inclined to think however that the facts warrant more than the creation of a new family of Ulotrichales to receive it. We entirely concur with Bohlin in removing the septate cœnocytic forms, *Cladophora* and its allies, away from the neighbourhood of the Ulotrichaceæ to the Siphoneæ next the Valoniaceæ, an affinity which has often been suggested, but apparently never expressed in a scheme of classification. Bohlin's removal of the Œdogoniaceæ from the Confervoideæ, and his establishment of a separate series—the Stephanokontæ—for its reception, also seems justified by the numerous unique characters of the family.

Bohlin has also removed *Vaucheria* from the Siphoneæ and included it in the Heterokontan class as the type of a new series, the Vaucheriales. Its position here must be admitted to be isolated, but certainly less so than among the pure-green Siphoneæ, where, in spite of its constant use in lectures and text-books as an elementary type of the group, it has always seemed an excessively anomalous genus.

In the class of Glaucophyceæ will be included those forms of Algæ (other than Cyanophyceæ) in which a blue pigment is associated with the chlorophyll.

The Green Algæ of which we shall treat will therefore be arranged in the following groups.

Class I. Chlorophyceæ (Isokontæ).
  Series 1. Protococcoideæ.
  ,, 2. Siphoneæ.
  ,, 3. Ulotrichales.
  ,, 4. Ulvales.
Class II. Stephanokontæ.
  Series 1. Œdogoniales.
Class III. Conjugatæ.
Class IV. Heterokontæ.
  Series. 1. Chloromonadales.
  ,, 2. Confervales.
  ,, 3. Vaucheriales.
Class V. Glaucophyceæ.

Class I. – CHLOROPHYCEAE (ISOKONTAE.)

Plant-body unicellular, or coenocytic, or consisting of an aggregation of cells or coenocytes which ranges from a loosely combined indefinite cell-complex to a highly integrated thallus of definite form. This coenocytic or multicellular aggregate may retain more or less the isodiametric form of the typical unicellular organism or by localised growth may extend as a plate-like structure, or, in the majority of cases, as a simple or branched filament. The branches are either free, or joined laterally with one another, or interwoven to form a thallus of compact structure.

Cell or coenocyte containing one or more bright-green chromatophores (chlorophyll unmasked by any other pigment) of very various form, *producing starch and nearly always including one or more pyrenoids.*

Cell-wall generally giving the cellulose reactions, solid or more or less mucilaginous.

Reproduction in most cases effected by naked biflagellate swarmers with a colourless, usually pointed, anterior end to which the two flagella are attached. On one side there is often an eye-spot, and the posterior end is rounded and possesses a more less definite basin-shaped chromotaphore with or without a pyrenoid. On coming to rest the swarmer germinates to form a new individual. In some forms these swarmers are facultative gametes, *i.e.* each is capable under certain conditions of fusing with a similar swarmer to form a zygote, but *in most forms obligate gametes occur. These are similar but smaller swarmers (planogametes) which may be all alike (isogametes) or may be differentiated into megagametes,* which are relatively passive *(female) and microgametes* which are relatively active (*male*). *The culmination of this differentiation occurs when the microgamete becomes a much-reduced swarmer* (*antherozoid*) *and fuses with the egg* (*oosphere*), *which is a purely passive and non-motile megagamete, to form an oospore* (*oogamy*). The germination of the zygote or oospore may be direct or indirect.

Reproduction may also be effected by detachment in the multicellular and cœnocytic forms of unspecialised vegetative parts from the thallus (fragmentation), by detachment and germination of slightly specialised immotile thick-walled cells (akinetes) which in the unicellular forms are produced by the direct metamorphosis of the vegetative individual, and by the formation of special immotile reproductive cells (aplanospores) due to the rounding off and investment with a new wall of one or more masses of protoplasm within a vegetative cell or coenocyte.

[Many Algæ belonging to various families of the Chlorophyceae have the power of passing into the "palmelloid condition" at the onset of unfavourable circumstances or of other changes in their environment. This condition is attained by abundant vegetative division, the daughter-cells, which are always rounded and devoid of specific characters, remaining aggregated within the confluent mucilaginous mother-walls. The phylogenetic significance of this biologically important phase is not clear.]

Series I. **Protococcoideæ.**

Plant-body motile or immotile, *most frequently unicellular* or a simple globular coenocyte, *often an indefinite mucilaginous colony of loosely aggregated cells, sometimes a definite coenobium* of cells or of simple coenocytes, never a definite multicellular thallus or a complex coenocyte. The whole range of reproductive processes characteristic of the Chlorophyceae is exemplified within this group.

[This series is probably to be regarded as a grade-grouping of all the primitive forms of the Chlorophyceae, which may be considered to have been evolved from the Chlamydomonas-type, along lines exhibiting the divergent tendencies which find their higher expression in the other three series respectively.]

(*a*) PLANT-BODY FLAGELLATE AND MOTILE DURING THE DOMINANT PHASE.

Fam. I. Volvocaceae.

Plant-body unicellular or consisting of a definite coenobium of cells which are either superficially coherent within a swollen mother-cell-wall or are united together by protoplasmic processes. All the cells, whether single or in coenobia, are flagellate and motile in the vegetative condition.

Cells, rounded or more rarely tapering, with a specialised anterior end of non-granular protoplasm which bears *2 (rarely 4) flagella* and contains usually two contractile vacuoles. A single nucleus in the centre, sometimes enveloped by the *more or less basin-shaped chloroplast* (colourless in Polytoma) *which occupies the posterior end. Starch is the characteristic anabolite and one or more pyrenoids are found in the chloroplast.* An eye-spot generally occurs on the periphery of the cell near the anterior end and a cell-wall is nearly always present.

Reproduction, either only by vegetative division usually into 2, 4, or 8 daughter individuals, or more commonly *also gamogenetic by the isogamous union of planogametes*, produced similarly to the vegetative daughter individuals, but in greater numbers, rarely by the heterogamous union of planogametes or by oogamy.

The first cell-division-plane is typically transverse to the long axis of the cell.

[The vegetative division in this family which gives rise at once to new motile individuals is strictly comparable with the formation of non-conjugating swarmers (asexual reproduction by zoospores) in the other classes of Green Algæ.]

[The coenobium is a special type of the aggregation of cells to form a colony, characterised usually by its high integration, and by the fact that no increase in the usually quite definite number of cells takes place after birth, but all the cell-divisions occur in the embryo while inside the mother-coenobium and all the resulting cells belong typically to the same generation.]

[According to modern views the Green Algæ are derived phylogenetically from the Flagellata, a group of unicellular organisms usually reckoned by zoologists as belonging to the Protozoa and containing a very varied assemblage of forms, many of which shew a mixture of animal and plant characters. The Volvocaceæ naturally connect the Green Algæ with the Flagellata, and on account of their motility and the general resemblance of their body to the Flagellate type are often included in the latter group. Klebs (1892)[1] however showed that a great consensus of characters united the Volvocaceæ with the Green Algæ, and separated them from all other organisms of the Flagellate type, and the case for their separation is in our opinion overwhelming. It will be convenient to insert here the characters of the Flagellata as distinguished by Klebs, for comparison with the diagnosis of the Volvocaceæ given above.

Flagellata. Body unicellular or a colony of cells, cell uninucleate with a thick or thin external layer of protoplasm the *periplast* in which *amœboid changes of form* may take place. Outside this a non-living investment of the cell is frequently present; it may present the most varied form and is often not closely adherent to the body. Specialised anterior end of clear protoplasm bearing *one or more flagella.* One or more contractile vacuoles are present. Organism always remaining capable of movement. *Nutrition either holozoic* (solid food being taken by pseudopodia, through a specialized mouth, or otherwise), *saprophytic or holophytic.* In the last case the *chromatophores* are green or yellow and may take the form *of bands, plates or discs. True pyrenoids entirely absent.* Paramylon, leucosin or a fatty oil the visible anabolites. *Starch entirely absent. Reproduction by simple longitudinal division,* usually beginning at the anterior end of the body. Individual always capable of forming resting cysts. *Gamogenesis apparently entirely absent.*]

Sub Family I. Polyblepharideæ.

Body unicellular of varied shape *without cell-wall, capable of some change of form. Flagella four (rarely more). Typical Volvocine chromatophore, pyrenoid and eyespot. Reproduction by longitudinal division.* Gametes unknown. Resting cysts formed directly from motile individuals.

[Special interest attaches to this family since it clearly exhibits a mixture of Flagellate and Volvocine characters.]

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[1] KLEBS. Flagellatenstudien. *Zeitschr. f. wiss. Zool*, 1892.

Genera.

1. *Polyblepharides.* Dangeard, 1887.
   Body conical with broad end anterior, Flagella 6–8.

2. *Pyramimonas.* Schmarda.
   Body conical 4-lobed. Chromatophore 8-lobed. Flagella 4, inserted between the lobes.

3. *Chloraster* Ehrenberg.
   Body with 4 contractile lobes. Flagella 5.

4. *Tetratoma.* Bütschli.
   Body spherical or ovoid. Flagella 4 inserted separately.

II. Chlamydomonadeæ.

Body unicellular usually spherical or oval, rarely spindle-shaped *with a distinct cell-wall. Flagella typically two* (rarely four). *Chromatophore typically basin–shaped* enveloping the colourless peri-nuclear protoplasm. *Pyrenoid typically one,* in the posterior part of the chromatophore. Eye-spot usually present, lateral.

Reproduction by successive divisions in planes at right angles to one another, the first usually transverse, the cell nearly always coming to rest before the beginning of division, giving rise to 2, 4 or 8 daughter cells, which rapidly acquire the characters of the motile individual. *Planogametes similar to the vegetative individuals* but smaller and usually naked, produced in the same way, but up to 64 in a cell. Clothed anisoplanogametes found in some species, the entire contents of megagamete acting as an egg. Akinetes and palmelloid stages are also sometimes formed from the vegetative individuals.

Genera.

1. *Carteria.* Diesing, 1868.
   Body variable in shape mostly with a very thin cell-wall. Flagella 4. First division-plane longitudinal.

2. *Chlamydomonas.* Ehrenberg, 1832.
   Body spherical or oval with a thin closely adherent cell-wall. Flagella 2. Chromatophore typically basin-shaped with a single pyrenoid, sometimes reticulate or banded. First division-plane longitudinal, longitudinal rotating to the transverse position, or transverse. Conjugation of naked isogametes or clothed iso- or anisogametes, the last shewing true oogamy
   (*C. Braunii*).

[This genus holds a unique position among the Green Algæ, and indeed among the whole of the Green Plants. It may be regarded as the phylogenetic starting point of the various lines of Chlorophyceous descent. The history of these is a history of the intercalation of a vegetative phase between two successive motile (Chlamydomonadine) generations, these motile phases being retained for reproductive purposes as zoospores and gametes; in the oogamous types the male gamete alone remains motile, and constitutes in the Archegoniate series the last remaining representative of the Chlamydomonadine cell.

The co-existence within the limits of an undoubtedly natural genus of the most primitive form of gamogenesis (the conjugation of equal clothed gametes) with a gamogenesis which has the essential characteristics of true oogamy is also a feature of unique interest.]

3. *Sphærella.* Sommerf.

Body of *Chlamydomonas*-type but with wall widely outstanding, connected by protoplasmic threads. Pyrenoids one, two or many.

4. *Chlorogonium.* Ehrenberg.

Body elongate, spindle-shaped, with a very thin closely adherent cell-wall. Flagella 2. Chromatophore not well defined, spongy with colourless protoplasm in the meshes. Pyrenoids five or more. Numerous contractile vacuoles distributed through protoplasm. First division-plane transverse. Conjugation of naked isogametes.

5. *Cercidium.* Dangeard, 1887.

Body as in *Chlorogonium*, but with only two pyrenoids, anterior and posterior to the nucleus.

III. Polytomeæ.

Body as in Chlamydomonadeæ, but colourless, and usually without chromatophore-stroma.

Reproduction as in Chlamydomonadeæ, but division taking place during motile condition. Daughter individuals are facultative gametes.

1. *Polytoma.* Ehrenberg, 1831.

Body with a thin closely adherent or slightly outstanding cell-wall.

2. *Chlamydoblepharis.* Francé, 1894.

Body with a very thick outstanding wall, often pierced by larger or smaller pores.

(to be continued).

R. Madley, Printer, 151, Whitfield Street, W.

THE
NEW PHYTOLOGIST.

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THE OLD WOOD AND THE NEW.

By D. H. Scott, F.R.S.

THE appearance of secondary wood and bast, with power of indefinite increase by means of cambium, was the most important event in the anatomical evolution of the vascular plants. We now know that this advance was made exceedingly early, and in many lines of descent; at the commencement of the Carboniferous epoch, we find secondary growth well established in every group of Vascular Cryptogams, as well as in the Gymnosperms which had already sprung from them.[1] Its common occurrence among the Pteridophytes of Palaeozoic age—a result which we owe in great measure to the discoveries of Williamson—is specially interesting, because their representatives at the present day have, for the most part, lost this power.

The object of the present article is to trace briefly, in one series of forms, some of the structural changes induced by the introduction of secondary growth, confining our attention to the wood, which, from its good preservation in fossil plants, is best suited for our purpose. It is proposed to follow the competition, if we may so call it, between the new Phanerogamic secondary wood, and the old Cryptogamic primary wood, which the former first supplemented and then displaced. The phrases Cryptogamic and Phanerogamic wood are due to the French school of palaeobotanists, who applied them, in the first instance, to the centripetal and centrifugal wood, so sharply contrasted in the stems of fossil Lycopods. The distinction is valuable and suggestive, even though the series to which the French authors applied it be not that which actually led up to the higher plants. Centripetal wood is not, of course, limited to Cryptogams, nor centrifugal to Phanerogams—if it were so, any evolutionary sequence would be out of the question—but each may be taken as characteristic of its class; as we approach the Flowering Plants the latter increases at the expense of the former. Some of the steps of the transition have been acutely traced by the French observers; if their inferences as to the course of descent do not hold good, it is because they did not sufficiently realize that a similar gradation was followed in several distinct phyla.

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[1] We are not here concerned with secondary growth in other than vascular tissues (e.g.: periderm) or in other than vascular plants (e.g.: stipe of Laminariaceous Algæ).

It need scarcely be pointed out that the development of the primary wood in the stems of Cryptogams is not necessarily centripetal; the reverse holds good in various simple types of stem, e.g.: the Hymenophyllaceæ. Whether the centripetal primary wood was the most primitive or not is immaterial to our purpose; in the series of stems with which we are concerned, the primary wood is, as a matter of fact, wholly or largely centripetal, a fact which facilitates its distinction from the secondary wood superadded in the centrifugal direction by the cambium. Such part of the old or Cryptogamic wood as was from the first centrifugal could easily accommodate itself to the new conditions, and merely tends to become merged in the secondary tissues. The centripetal part, on the other hand, became more and more superfluous as the possibilities of indefinite extension in the opposite direction came to be realized. Here no compromise was possible; the old wood was becoming a useless encumbrance and had to go.

We begin our series with the fern-like genus *Heterangium* (Lower Carboniferous to Permian). Here the old wood is still dominant, occupying the whole interior of the pithless protostele. Only the peripheral groups of primary tracheides are in direct continuity with the leaf-traces; the central wood is purely cauline. This may indicate a very primitive condition, if leaf-trace wood and central wood had a distinct origin, as suggested by Tansley and Chick.[1] The leaf-trace strands have a little primary centrifugal xylem, but this is insignificant in comparison with the great centripetal mass. Secondary growth began late, and did not usually attain any very great extent; the new wood is an auxiliary to the old, but does not yet attempt to displace it.

Megaloxylon (Coal-measures). In this genus, discovered by Mr. Seward, the primary wood, as in *Heterangium*, still occupies the whole interior of the stele (here of large dimensions) but shows a striking differentiation. The exarch leaf-trace strands are very distinct and consist of ordinary elongated tracheides, but the tracheides of the central mass are extremely short, and ill-adapted for conduction. The old central wood, finding itself relieved of its original duty by the new secondary tissues, has, as it were, taken the alarm, and by adapting itself to a new function—that of water-storage—is able, for a time, to maintain its existence.

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[1] Ann. of Bot., vol. xv., p. 35. 1901.

Lyginodendron (Lower Carboniferous and Coal-measures). Here the central wood has disappeared altogether, and is replaced by pith; from this stage onwards, leaf-traces and secondary wood are alone represented. The structure of the leaf-trace strands themselves, however, is precisely the same as in *Heterangium*. Everything supplementary to them is henceforth supplied by the secondary wood alone. *Lyginodendron* is the typical stem for complete persistence of the centripetal wood in the leaf-trace system, while it has disappeared elsewhere. The bundles of the *stem* have here a structure identical with that of the *leaf*-bundles in Cycads. In the leaf of *Lyginodendron* the bundles were still concentric, and therefore Fern-like, as was the general habit.

Calamopitys[1] (Lower Carboniferous). In *C. fascicularis* the grade of structure is almost like that of *Lyginodendron*. The leaf-trace strands are largest where they leave the pith, and are here typically mesarch, with well-developed centripetal wood; traced downwards from this point the latter becomes much reduced, but does not wholly disappear. *C. beinertianum* goes a step further. Here the leaf-traces only have centripetal xylem where they approach their exit; lower down in the stem they lose it altogether, so that in most of the strands around the pith the structure is purely endarch. This stem thus marks an important step towards the characteristic Gymnospermous anatomy. *Calamopitys*, judging from the German species, *C. Saturni*, was probably still Fern-like in habit.

Pitys (Lower Carboniferous). This genus diverges a little from our series; it no doubt approached the Gymnosperms nearly, and was perhaps itself an early representative of the Cordaiteae[2]. The structure is remarkable; in *P. antiqua* (Witham's "Lennel Braes Tree") a great number (40-50) of mesarch xylem-strands surround the large pith, but they are very small, and most of them are embedded in the tissue of the pith, and thus isolated from the rest

[1] A most inappropriate name, maintained in deference to the law of priority. There is no real affinity to Calamarieae.

[2] The great trunk in the garden of the Natural History Museum belongs to a species of *Pitys*.

of the wood, except where they bend out to contribute to the leaf-traces. This displacement of the primary wood inwards probably indicates some change of function. *Pitys*, however, is an example of the retention of the old form of wood (reduced and somewhat altered, it is true) in trees which probably had already become Gymnosperms.

Poroxylon (Upper Carboniferous and Permian) is pretty completely known, so far as the vegetative organs are concerned, and is interesting from its evident affinity to the Cordaiteae. The stem-structure is about at the average grade of the genus *Calamopitys*. The leaf-trace xylem-strands are almost wholly centripetal in the upper part of their course, but the centripetal wood dies out about eight internodes below their entrance into the stele. The leaves, though simpler in form, were structurally much like those of existing Cycads.

Dadoxylon Spenceri (probably Upper Carboniferous) has a dense wood of very Coniferous appearance; the leaf-traces pass out in pairs, as in the recent Maidenhair-Tree (*Ginkgo*). At the border of the pentagonal pith, near the angles, we find a few very small primary xylem-strands, which, where they approach their exit as leaf-traces, have a distinct mesarch structure, though elsewhere centripetal xylem cannot be detected.

It is interesting to note that in *Ptychoxylon* (Permian) a genus somewhat remote from the series we are considering, but with undoubted Cycadean affinities, the leaf-traces only retain their centripetal wood in passing trhough the cortex of the stem, and have completely lost it before they enter the stele.[1]

Lastly, we come to *Cordaites* itself, which is anatomically on the same level as recent Cycads; centripetal wood has wholly disappeared from the stem, while it still forms the main constituent of the xylem in the bundles of the leaf. This statement applies to those specimens, from the Coal-measures and Permian, which have been referred with certainty to this family. As has been pointed out above, it is extremely probable that some of the stems which retained more or less of the old wood, also belonged here.

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[1] This stem has a very complicated secondary structure, with bands of inverted vascular tissues around the pith, but, as Renault has shown, the centripetal wood which occurs in this position is secondary, and has nothing to do with the Cryptogamic or primary centripetal wood. See Flore fossile d'Autun et d'Epinac. Pt. 2, p. 410.

In the series we have followed, we have seen how the centrifugal wood, enormously reinforced by secondary growth, has gradually exterminated the old and unprogressive centripetal wood, which becomes more and more a mere vestigial structure, until it is lost altogether. The Cryptogamic wood was, in fact, doomed, from the moment when secondary growth, with its unlimited possibilities, established itself. It has only survived as long as it has, because of the conservatism of the foliar bundles. In the leaf there was not much demand for secondary tissue, and so the old wood was long able to hold its own—down to the present day in the Cycads. In the leaves of Conifers, too, as Mr. Worsdell has given us good grounds for believing, the centripetal wood still persists in the form of transfusion-tissue. It has survived here by the help of a change of function, similar to that, which, as I have suggested, enabled the central wood in the stem of *Megaloxylon* to justify its existence, after it had become superfluous as a conducting tissue.

For a time the leaf-traces connected with the foliar bundles retained the old wood, and they retained it longest in the part of their course nearest the leaf.

In the peduncles of some Cycads, organs of limited duration with little need for secondary growth, the old centripetal wood has lingered on, in a sadly reduced form, to the present day, but can scarcely now be of much use to the plant—"superfluous lags the veteran on the stage!"

These are the only stem-structures in Phanerogams which still retain the Cryptogamic wood, if we except the curious case of Rothert's *Cephalotaxus Koraiana*, where centripetal wood (not secondary in origin) seems to have re-appeared in great force; so isolated a case can scarcely be regarded as a survival.

The series which we have followed—from *Heterangium* to the Cordaiteae and Cycads—is not a chronological one, and makes no claim to represent the true course of descent. It is only, however, among Palaeozoic plants that our transitional forms occur; by the time we reach the Mesozoic Gymnosperms, the old primary wood has, so far as we know, disappeared from the stem. Further, there is no doubt that the extinction of the centripetal wood coincides, on the whole, with the general replacement of Cryptogamic by Phanerogamic characters. By the use of such provisional series as that which we have sketched in the preceding pages, we may hope in time to come nearer to our goal, the discovery of actual lines of descent, just as the morphologist, by first determining his parastichies, is ultimately able, by their help, eto find the true genetic spiral. In the present paper only on series has been considered, and that with reference only to one particular character; possibly we may endeavour to fill in other lines at some future time.

REVIEW.

On the Structure and Affinities of Fossil Plants from the Palæozoic Rocks.—IV. The Seed-like Fructification of *Lepidocarpon*, a genus of Lycopodiaceous Cones from the Carboniferous Formation. By D. H. Scott, M.A., Ph.D., F.R.S., Hon. Keeper of the Jodrell Laboratory, Royal Gardens, Kew. *Phil. Trans.* 1901.

At the present moment the appearance of this notable memoir is particularly opportune. The gap between the Pteridophytes and Spermaphytes has been appreciably norrowed by the discoveries in *Ginkgo* and the Cycads. But the affinities of the Spermaphytes may still be regarded as an open question. To each of the three great phyla of Pteridophytes has the possibility of seed production been attributed. Some hold to the view that the Lycopods have blossomed forth into Spermaphytes; others search for evidence of seeds on Calamites, whilst a third view, that of the Filicinean ancestry of Cycads, and probably of Gymnosperms generally, has become familiar to Botanists in this country through the able exposition of his views by the author of the subject of this notice.

In *Lepidocarpon*, the name given to certain peculiar Lycopodinean cones with seed-like fructifications, we touch new ground and are shown a structure, which, whether a seed or not on strictly formal lines, may shed considerable light on the question of the possible way in which the structure we recognize as a seed may have been evolved.

The essential facts of the discovery are briefly as follows—The supposed Gymnosperm seed which Williamson erroneously referred to *Cardiocarpon anomalum* of Carruthers is now shewn to be a Lepidostroboid macrosporangium containing a single functional macrospore and provided with an integument which grows up from the body of the sporophyll. This integument, together with the sporophyll, completely envelopes the sporangium. A number of cones have been examined by Dr. Scott, viz.—(1) Younger stages of macrosporangiate strobili having the radially elongated sporangia seated on the sporophylls precisely as in *Lepidostrobus*. The only peculiarity of this stage, and it is an important one, resides in the fact that only a single functional macrospore is present in each sporangium, accompanied by the other three members of the tetrad in an abortive condition. The organisation of the cone is wholly that of a *Lepidostrobus*, for which it may readily be mistaken. (2) An older cone, differing from the foregoing in the presence of integumented in addition to naked sporangia. The integument grows up from the flanks of the sporophyll, meeting above the sporangium. The line of closure of the integument is a long crevice running the whole length of the upper surface of the sporangium. This slit has been compared to a micropyle. A point of interest and perhaps of significance is the existence of numerous non-integumented sporangia, having the appearance of maturity in their tissues. Dr. Scott regards them as arrested stages rather than merely young ones, though they may be taken as representing in essentials the young condition hardened and matured, and thus better fitted for preservation than specimens in the normal course of development. The meaning of this frequent arrest is not easy to understand, but it seems futile to speculate on the matter till more developmental data are available. (3) a microsporangiate cone from the same block as one of the younger macrosporangiate strobili, and associated with detached integumented and non-integumented sporangia. This cone, whose reference to the same species seems more than probable, has a peculiar interest in that its sporangia are integumented in the same way as are the macrosporangia, though the enclosure is not so complete. The homology of the integuments in the two cases seems evident.

In addition to these cones there have been examined a large number of detached sporophylls with integumented and non-integumented macrosporangia. In a few instances among the former (the "seeds") the macrospore contains a prothallium. The prothallium shows peculiarities suggestive of archegonia and possibly of an embryo, but the data are not sufficiently precise for a certain determination.

Evidence of pollination has not been found. No organ is present that can be termed a pollen-chamber, nor have microspores been found within the slit-like micropyle; assuming for the moment that we have here a true seed, where would one search for a pollen-chamber? In the Cycads and in the fossil Gymnosperm seeds the nucellus has a definite apex in which the chamber is excavated. It is a reasonable conjecture that the development of a pollen-chamber is only an adaption from an ancestral sporangial dehiscence. But we know nothing about the dehiscence of the bulky sporangia of *Lepidostrobus*, which in all probability was irregular and undefined. *Ex nihilo etc.* On this view the absence of a pollen-chamber in the present case is intelligible.

Turning to the alternative hypothesis that the "seeds" were not real seeds, but that all the specimens observed, whether with or without prothallia, were still unfertilized or even unpollinated, Dr. Scott remarks—"If this were so, the organs in question were certainly not true seeds, *though it is possible that the evolution of true seeds may have started in the same way*." *Lepidocarpon* may be regarded as representing the lowest member of a series (not of course a phylogenetic series) in which the macrosporangium became integumented, and, unpollinated and unfertilized, fell to the ground. The next stage may be represented by the fossil Gymnosperm seeds in which the evidence points to a shedding of an integumented macrosporangium, already pollinated but not yet fertilized.

A further advance is perhaps represented by *Cycas* and *Ginkgo* where the seed is already fertilized at the time of its detachment, but as yet no embryo has been developed. Finally we come to *Pinus*, which is not only fertilized but embryonated as well, giving us the structure upon which we base our definition of a seed.

In such a series we note amongst other things (1) a prolongation of the period of retention on the parent plant in relation to the time of occurrence of the act of fertilization; (2) a gradual retarding of the maturing and hardening of the integument; (3) an increase of the intimacy between sporangium and integument; at the outset (*Lepidocarpon*) the integument grows up freely from the sporophyll as a mere sporangial envelope and is in nature a sporangial envelope rather than a seed coat (the microsporangium is similarly provided). In the second stage the coat has become a definite portion of a seed, still probably free from it, though subordinated to the special seed requirements. Finally in the late stages, in the typical *seeds* on which our morphological conceptions are based, a large degree of coalescence obtains between nucellus and testa.

Such a series as the above we know to have actually existed, though it is perhaps premature to conclude that seed-plants proper have passed through a similar progression. The filling up of the lacunæ in our knowledge of these cones will be awaited with interest. That the recognition of these very elementary forms in the evolution of seeds must needs upset present morphological conceptions based on a study of recent plants seems evident. And in due course, as our knowledge becomes more precise, these conceptions must be reformulated.

As regards the phylogeny and affinities of the Gymnosperms *Lepidocarpon* affords no real support to the view that they were derived from Lycopods. "At present *Lepidocarpon* stands isolated. Its reproductive bodies, as I have endeavoured to show, present important analogies with true seeds, but there is nothing to indicate affinity with any of the existing groups of Spermaphytes. Those who hold to the belief that the Gymnosperms, or part of them sprang from Lycopods, may find in the discovery of *Lepidocarpon* some support for their views. In spite of its seed-like organ, however, the new genus was a true Lycopod, and shews no indication of transition to any other group. The mere fact that these plants produced a reproductive body agreeing in many respects with a true seed, is no proof that they belonged to the line of descent of any of the known types of seed-bearing plants. *Lepidocarpon* is of great interest as demonstrating to us one way in which seeds may have originated, but we have no right to assume that it presents to us the actual origin of the seeds of Phanerogams. To take an analogous case : *Bennettites* affords the earliest known instance of an angiospermous fructification ; yet botanists are agreed that it has no affinity with the Class Angiospermæ. . . . . The balance of probability is in favour of the new genus representing merely a short branch of the phylogenetic tree, parallel, perhaps, or even convergent with the great spermaphytic phylum, but without genetic connection with it."

That there has been published almost at the same time as the discovery of *Lepidocarpon* an account[1] of certain N. American species of *Selaginella* in which a somewhat comparable approach is made to a seed-like condition, is full of interest. It would almost seem indicated in this case that it may be possible to correlate the effect of season and environment upon the nascent structure with the degree of similitude to a seed attained. Whatever the fossils may tell us, and they are astonishingly instructive at times, it must be remembered that we are far from having extracted all possible information from plants still living. The realisation of the hope of morphologists that we may ultimately possess a complete chain of data shewing the lines along which seeds have been evolved may be remote, but for all that it seems well in sight. That *Lepidocarpon* will play a part in the solution of this question there can be little doubt. F. W. O.

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[1] F. M. Lyon. A Study of the Sporangia and Gametophytes of Selaginella apus and S. rupestris.
—*Botanical Gazette*, vol. xxxii., 1901.

NOTES ON CURRENT LITERATURE.

Marine Bacteria and their Activity.

IT is well known, from the observations of Fischer, that Bacteria are found distributed generally in the sea, but of the part that they play in the general "economy" of the ocean we have very little knowledge. There is a special need for information as to the metabolism of the marine bacteria. In connection with this point Beijerinck has studied a small number of the luminous bacteria of the sea, and Russell has shown that certain aerobic bacteria from the Atlantic sea-bottom are able to reduce nitrates to nitrites, but in spite of these researches we are entirely ignorant as to the "circulation of nitrogen" in the sea. We have no information as to whether a process of nitrification takes place in the ocean at all, or even if there exist marine organisms which are capable of fixing free Nitrogen; and as to the opposite process of denitrification, it has not hitherto been clear that this process could be carried on by the common non-luminous bacteria of the sea, or that bacteria found there conditions suitable for this process.

In a recent paper—"Studien über Meeresbakterien. I. Reduction von Nitraten und Nitriten," von H. H. Gran: Bergen's Museums, Aarbog, 1901, No. 10—the author has investigated the power of denitrification possessed by bacteria collected from the surface of the North Sea, off the coast of Holland, and also the conditions under which the process takes place. The species commonly met with seemed to be more than twenty in number, and fell roughly into four classes. (1) Those that quickly reduced nitrates and nitrites to free nitrogen without the formation of ammonia. (2) Those that easily reduced nitrates to nitrites, but the latter only with difficulty and with the formation of a certain amount of ammonia. (3) Those that could not reduce nitrates to nitrites, but reduced nitrites slowly. (4) Those that were unable to reduce either nitrates or nitrites, and were also incapable of assimilating them. Of the forms found only a small number played an important part in denitrification, of which three, having a specially energetic power of reduction, were more closely studied and described. The supposition, that the denitrifying bacteria found might be only land forms accidentally present in the sea, was recognised, but when investigated was found to be untenable.

The conditions necessary for the process of denitrification were investigated in some detail. It is shown that the process occurs under certain conditions of temperature, of supply of oxygen and of nutrition by means of organic material. The first two conditions are such as would be easily satisfied in the natural state in the sea. The amount of nitrogen reduction was found, however, to vary both with the kind and quantity of carbon-containing food material. Mannite was found to be the most active substance in this connection, but it required about four times the quantity of mannite to bring about the reduction of a given quantity of nitrite.

The conclusion to be drawn from these observations is that denitrification takes place in tbe sea, where there is a sufficient quantity of organic material. It will therefore probably be found to occur near the shore where there is a quantity of detritus from the land; but whether such a process plays an important part in relation to the nitrogen circulation of the ocean, must be left to future researches to decide. The occurrence of denitrification to any considerable extent in the open sea seems somewhat improbable; there is in fact, as yet, no evidence of the presence of denitrifying bacteria in such waters. V. H. B.

MISCELLANEOUS NOTES.

Mr. Buysman's Herbarium Specimens.

Mr. Buysman writes that he has reduced the price of his herbarium sheets, described in our last issue, to sixpence each.

PROFESSOR VINES AND THE CLADOPHORACEÆ.

In the introduction to "A Revision of the Classification of the Green Algæ," which appeared in our last issue, it was rather carelessly stated that the often suggested affinity of the Cladophoraceæ with the Valoniaceæ had "apparently never been expressed in a scheme of classification" before the appearance last year of Bohlin's paper on the phylogeny of Algæ and Archegoniatæ. Professor Vines writes to point out that in his "Students' Text-Book of Botany," (1894) the Cladophoraceæ (as also the Hydrodictyaceæ) are associated with the Siphoneæ *(sensu stricto)* in a larger group Siphonoideæ. The authors regret that they had forgotten this at the moment of writing. The fact that De Toni in his "Sylloge" (1889) included Valoniaceæ in Cladophoraceæ, though he placed both in the old Confervoideae, might also have been mentioned with advantage.

CORRESPONDENCE.

STAINING AND MOUNTING UNICELLULAR ORGANISMS.

To the Editor of "THE NEW PHYTOLOGIST."

SIR

In answer to a letter in your last number asking for information as to methods of making microscopic preparations of unicellular organisms, I would suggest that a method, both simple and satisfactory, has yet to be devised. The old-fashioned method of drawing drops of fixative, stain and mounting medium under the cover glass generally ends in the loss of most of the material, and is besides very laborious, especially if the fixative and stain require to be washed out. Drying on the slide, preferably after fixing with osmic vapour, etc., sometimes gives better results than would be expected from the drastic nature of the treatment, but is not to be relied upon.

The method of Overton (see Zimmermann's Botanische Microtechnik p. 29) has, however, given me very satisfactory results, but can hardly be considered as a simple process. It is necessary that the material be in absolute alcohol. I keep my material (after fixing, washing, and bringing up through the alcohols, by decantation, in small glass tubes) in 70% alcohol, which immediately before use is replaced by absolute alcohol. A drop of this fluid, together with the objects to be studied, is placed by means of a pipette upon a slide, the alcohol is allowed in part to evaporate, and then a drop of dilute celloidin (or collodion) is added. The slide is manipulated so that the celloidin forms a very thin layer, and directly the solution ceases to flow, the slide is placed in 85% alcohol, which very soon sets the celloidin firmly. The objects are now enclosed in a thin, but very permeable film, so that they can be stained in haematoxylin, carmine, etc., and in certain anilin stains such as safranin; the use of certain other anilin stains, such as gentian-violet, must be avoided, as they deeply deeply stain the celloidin film. The layer of celloidin becomes quite transparent in glycerine and canada balsam, so there is no necessity for its removal. Both absolute alcohol and clove oil dissolve celloidin, so, if it is necessary to mount in balsam, the slide may be passed from 90°/₀ alcohol to anilin oil, and then, preferably after washing in xylol, to canada balsam. The great objection to this method is of course its complication, but by mounting in glycerine or glycerine jelly the trouble of clearing is done away with, though the preparation is not likely to be so permanent.

I am, Sir,

Yours, etc.,

Jan. 29th, 1902. V. H. BLACKMAN.

To the Editor of "THE NEW PHYTOLOGIST."

DEAR SIR,

One of the best methods of preparing unicellular organisms for microscopic examination is the following:—In a small glass bottle of about one ounce capacity place half an ounce of 1°/₀ osmic acid or Flemming's chromic acid mixture. By means of a pipette eject into it water containing the micro-organisms to be investigated. This may be continued until the solution is about half the original strength. Allow the organisms to remain in it for about one hour, until they have settled in a compact layer at the bottom of the bottle, then remove the fixing fluid; wash in water once or twice; add 30°/₀ alcohol; replace this by 70°/₀ alcohol, and, finally, preserve in methylated spirit.

The organisms may be stained in .5°/₀ solution of Haematoxylin in distilled water. In order to do this, remove the methylated spirit; wash in water; soak for a short time in strong alum solution, then wash in distilled water, and add the staining fluid. Allow this to act until the organisms appear deeply stained dark purple or black; remove the stain; wash in water and add again a strong solution of alum. In this the stain will be gradually washed out. Examine a few of the organisms from time to time under the microscope, and when sufficiently washed out, pour off the alum solution, and wash in water; add 70°/₀ alcohol, then methylated spirit, and finally replace by absolute alcohol. They should be thoroughly dehydrated by two or three changes of absolute alcohol, and, finally, this should be replaced by xylol. From the xylol the organism may be directly mounted in a solution of canada balsam in xylol.

This method is applicable to organisms which can be obtained in fairly large quantities at a time, such as Protococcus, Euglena, Desmids, Diatoms, Volvox, Paramoecium, Astasia, Yeast, etc. It appears a complicated method on paper, but is really very simple in practice.

Yours faithfully,

Feb. 1st, 1902. H. W.

ON THE SO-CALLED PHLOEM OF LEPIDODENDRON.

By A. C. Seward, F.R.S.,
University Lecturer in Botany, Cambridge.

(TEXT-FIGURES I. AND II.)

SINCE the publication of a paper by Witham of Lartington in 1832 "On *Lepidodendron Harcourtii*[1]," the anatomical investigation of the various types of trees and other plants that constituted the forests of the Coal-period has made rapid strides, more particularly during the last thirty or forty years. The genus *Lepidodendron* is one of the commonest and best known members of the Upper Carboniferous flora of the northern hemisphere, and we possess a fairly extensive knowledge of the structure of several distinct forms. One result of the more minute anatomical study has been to bring to light certain features, which tempt us to speculate on the environment of the Palæozoic plants. There is a fascination in endeavouring to utilise anatomical facts as indices of external conditions; a closer acquaintance with the structure of the plants' machinery enables us to revivify the tissues of petrified fragments, and to consider them as portions of a working machine, impelled by the same forces and working towards the same ends that govern the life-functions of living plants. In some respects the organization of the extinct types was not strictly according to the pattern which our knowledge of living plants has led us to regard as typical; our aim is, to be in a position to answer the question—was the physiological division of labour in a *Lepidodendron* stem essentially similar to that which we find in the nearest living representatives of the genus?

I wish to confine myself in the present article to one or two points, and to discuss as briefly as possible certain structural features, interpreted by some writers as being in accordance with modern types, but which I believe illustrate peculiarities in the mechanism and physiology of *Lepidodendron* stems.

We will restrict ourselves for the present to two species, *Lepidodendron fuliginosum* Will. and *L. Wunschianum* Will.[2] In *Lepidodendron fuliginosum* the stem possesses a single stele consisting of an axial mass of parenchyma surrounded by a cylinder of primary xylem, which becomes encircled, at an early stage in the growth of the plant, by a zone of secondary tissue consisting largely of serially arranged parenchymatous cells and including scattered groups of secondary tracheids. Beyond the primary xylem in a young stem or small twig, or external to the secondary xylem in an older or larger specimen, there is a cylinder of tissue internal to the cortex; this is limited by an endodermal layer, the position of which can be recognised in well preserved sections. It is the nature of this tissue, which consists of two well-marked zones, that I wish to discuss. In the other species, *L. Wunschianum*[1], as represented by a magnificent specimen from the Lower Carboniferous rocks of Scotland, there is a central pith of parenchyma surrounded by a ring of primary wood, but in this type the secondry xylem which makes its appearance at a more advanced stage in the growth of the plant, consists entirely of rows of scalariform tracheids and medullary rays. Beyond the xylem there is a zone of tissue similar to that in *L. fuliginosum*, and in both species numerous leaf-traces occur in the extra-xylem region, passing upwards in an almost vertical course before they bend outwards into the cortex.

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[1] Witham, 1832. "On *Lepidodendron Harcourtii*," *Trans. Nat. Hist. Soc., Newcastle-upon-Tyne*, 1832.

[2] These two species belong to the *Lepidophloios* section of Lepidodendroid plants.

Lepidodendron fuliginosum. The best specimens of this type that have come under my notice, as regards the preservation of the delicate tissues, are contained in the Binney collection, Cambridge.

It is unnecessary to repeat the detailed description of these specimens, which I published in the Proceedings of the Cambridge Philosophical Society in 1899[2], but the following passages may be quoted as dealing more particularly with those anatomical features for which Professor Weiss[3] has recently suggested a different interpretation. "The xylem of the stem is surrounded by a fairly broad band of short and slightly flattened cells constituting a tissue to which the term meristematic zone has been applied; the reason for this appellation is that in some of the sections certain cells in this region are in a state of meristematic activity, and an identical band of short-celled parenchyma in the large Dalmeny stem was found to be the seat of active cell-formation. The formation of secondary tissues has scarcely begun in the sections with which we are at present concerned, but such traces as exist favour the view expressed at greater length elsewhere, that the method of secondary thickening in Lepidodendroid plants differed considerabiy from that with which we are familar in recent plants, or in such fossil genera as *Calamites*, *Lyginodendron*, *Sphenophyllum* and others. . . . ." "Beyond the meristematic region there is a characteristic band referred to as the secretory zone. This tissue forms a well-marked feature in stems of *Lepidophloios fuliginosus*, *L. Wunschianus*, and other species; the elements composing it do not conform to the structural characters of ordinary phloem. The large clear spaces or sacs which form so prominent a feature in this region cannot, I believe, be satisfactorily explained as the result of decay previous to mineralisation; their appearance is strongly suggestive of sacs or spaces, formed, for the most part, during the life of the plant, by the separation and partial disorganisation of thin-walled cells. The constant occurrence of patches of a dark brown substance in this zone also points to the secretory nature of the tissue . . . The group of secretory tissue accompanying the xylem of a leaf-trace may be followed, in longitudinal and in transverse sections, into direct continuity with the broad secretory zone of the stem; but the elements of this tissue which form part of a leaf-trace, differ from the secretory zone in the narrower diameter of the cells and in the somewhat greater abundance of secreted substance. Neither in the structure of the main stele of the stem nor in the tissues of the leaf-trace do we find any set of elements, which exhibit histological features affording satisfactory evidence of the existence of either hard or soft phloem of the ordinary type . . . . The apparent absence of any well-defined phloem tissue is a fact of considerable interest; even in the large Dalmeny stem, in which the secondary xylem is 2·8 *cm.* in diameter, there is no indication of any tissue which can be identified anatomically with true phloem. Indeed in no stem of *Lepidodendron*, *Lepidophloios* or *Sigillaria* has typical phloem been so far satisfactorily demonstrated. The existence of the secretory zone suggests a physiological comparison of this tissue with normal phloem, on the ground that in certain recent plants laticiferous tissue has been considered as in part at least carrying out the functions of phloem; it is a probable view that this well-marked zone may have served the same purpose as the tissue which in recent plants usually presents the structural characters of phloem . . . Without discussing the question at greater length, the conclusion may be briefly stated, that the functions usually carried out in recent plants by elements possessing the structure of phloem, were in Lepidodendroid stems performed by tissues of a somewhat different type; probably the secretory zone of the stem and the secretory elements of the leaf-traces are physiologically comparable to phloem tissue, and in part to the laticiferous tissues in some recent plants."

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[1] It is possible that this plant is identical with *L. Harcourtii* With. See Seward and Hill, 1900. "On the structure and affinities of a Lepidodendroid Stem, etc." *Trans. R. Soc. Edinburgh*, vol. xxix, pt. iv., 1900, pp. 921 et seq.

[2] Seward, 1899. "Notes on the Binney Coll. of Coal-Measure Plants."

[3] Weiss, 1901. "On the Phloem of *Lepidophloios* and *Lepidodendron*." *Mem. Proc. Manchester Lit. & Phil Soc.*, vol. xiv, pt. iii., p. 1.

Professor Weiss has recently published an account of certain tissues in some exceptionally good specimens of *Lepidodendron fuliginosum* from the Cash collection of plants in the Manchester Museum[1]. His main object is to show that the tissue which I called the secretory zone does not differ materially from the phloem of recent Lycopodiaceæ—" Until it is disproved," he writes " that the cells of this phloem region are of such a nature as not to be able to effectively conduct and store organic material for the use of the secondary meristem we must look upon it as functionally representing the phloem, though it may differ from it in construction. But as a matter of fact it does not seem to differ materially from the phloem of recent *Lycopodiaceæ* except in such particulars as are probably connected with the absence of secondary thickening in recent *Lycopods* and the consequent diminished need of storing organic materia] within the stele." . . " That some of the elements of the phloem region may have been of the nature of laticiferous cells or may have united to form mucilage ducts is, of course, quite conceivable, even when the bulk of the elements made up a true phloem."

I am in agreement with Professor Weiss as regards the probably phloem-function of this tissue[2], but I do not agree with his conclusions as to its phloem-structure. The same writer goes on to say that he agrees with Dr. Scott[3] in regarding the phloem of *Lepidodendron* as fundamentally similar to that of the recent allies of the genus.

One of the photographs[4] reproduced in Professor Weiss' paper shows the cambium distinctly; in the stem he describes, a fairly thick band of secondary xylem has been produced, but the connection between the cambial tissue and the outermost additions to the xylem is not brought out very clearly. It is important to notice that the region of active meristematic growth is separated from the most external thick-walled xylem elements (in *Lepidodendron fuliginosum* parenchymatous elements form the greater part of the secondary wood) by several layers of cells. In other words, the region which is designated cambium is rather further away from the mature secondary xylem than it is in recent plants. The conclusion is, that I was mistaken in considering the disorganisation of the tissue, which I called the secretory zone, as connected with a secretory function, the resemblance to secretory groups being due to *post-mortem* changes in a zone of ordinary phloem. The more compact nature of the extra-cambial zone in the Manchester specimens may indicate that the tissue in question was not secretory, but in the absence of evidence furnished by longitudinal sections we cannot arrive at any satisfactory conclusion as to histological characters. It is a pity, as Professor Weiss says, that there are no longitudinal sections of the specimen; they alone can decide whether the groups of cells compared by him to sieve-tubes surrounded by companion-cells are of that nature, or if they are of the nature of short and delicate cells which would eventually become disorganised, leaving the oval spaces which usually characterise the 'phloem' regions in Lepidodendron. The clusters of so-called sieve-tubes and companion-cells are no doubt identical with those represented in fig. 3[1] of my description of the same species, and spoken of as "small elements enclosed by a thin oval membrane;" they are also indicated in some of the large vertical spaces represented in fig. 5 of the same paper[2]. The evidence at present available does not appear to me to support Professor Weiss' conclusion; I believe that these cell-groups are most probably preserved in the Binney sections as they existed during life; the fact that they are less disorganised in the Cash specimen of *Lepidodendron* does not afford proof that they did not possess a secretory function. We, have, in short, no satisfactory evidence of the sieve-tube nature of any of the elements in the tissue which Weiss describes as phloem. I do not wish to overlook the possibility that the features which led me to make use of the term secretory zone may be found to have been unsafe guides, and that they may afford another instance of the difficulty of distinguishing between original and secondary structures. It may be as Professor Weiss[3] has suggested, that the chemical and physical constitution of the walls of the elements of the extra-cambial tissue may have been such as to favour mucilaginous degeneration or other changes, which would tend to obliterate the original structure before petrifaction took place. The tissue in question may or may not have had a secretory function, but such anatomical evidence as we have before us does not appear to me to support the view that *Lepidodendron* possessed a phloem-tissue essentially similar to that of its recent allies. I entirely agree with the opinion that this band of tissue external to the cambium may have acted as phloem, but we require additional data before we can assert that it carried out its share of the plant's requirements by means of tissue-elements like those in the phloem of recent plants.

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[1] Weiss, 1901.

[2] Seward, 1899 P. 155.

[3] Scott, 1900. *Studies in Fossil Botany*, pp. 142, 143.

[4] Weiss, 1901. Fig. 2, Pl. II.

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[1] Seward, 1899. P. 147.

[2] *Ibid.* P. 151.

[3] Weiss. 1901. Pp. 13 *et seg.*

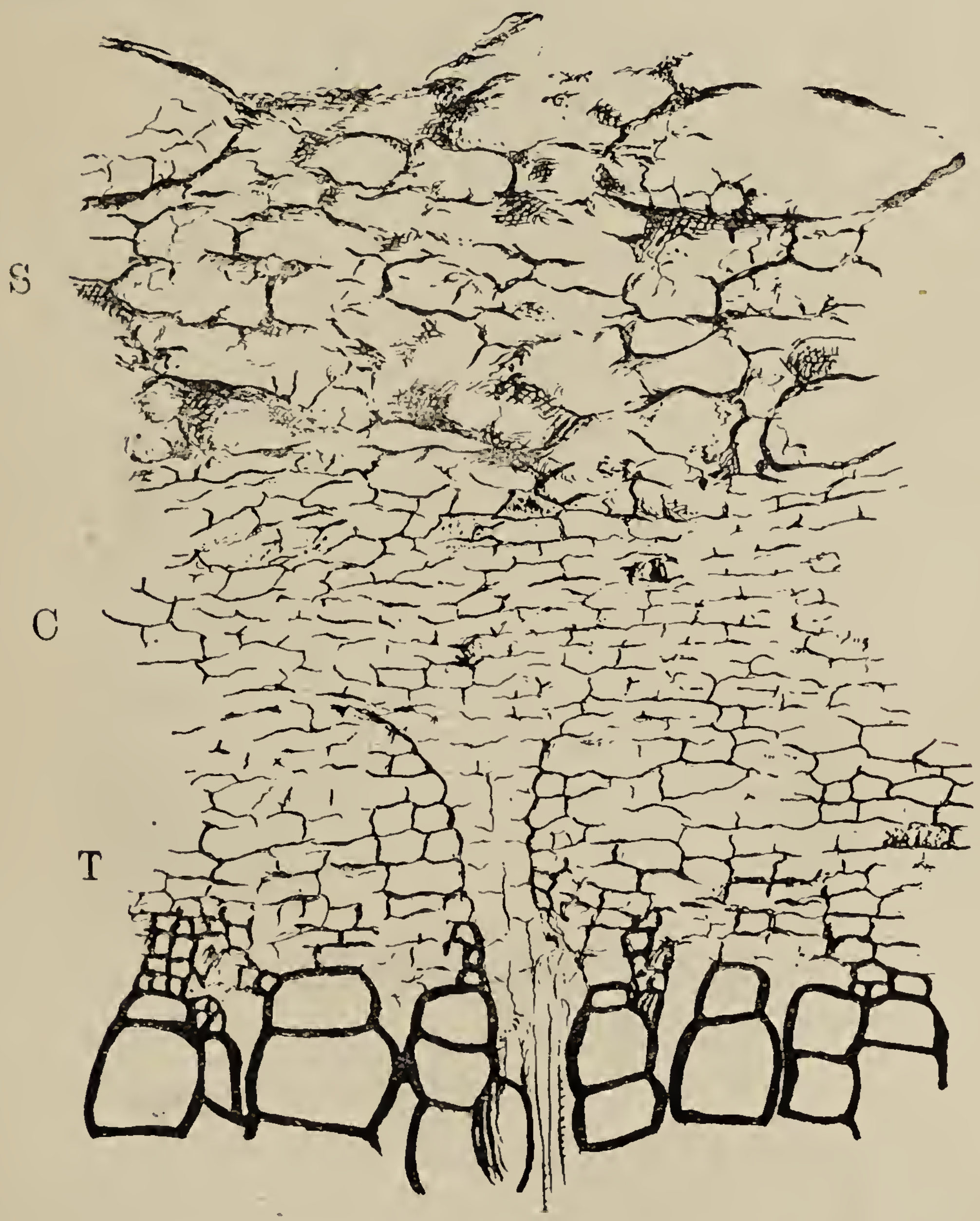

Figure 1. *Lepidodendron Wunschianum.*

Transverse Section. *T*, small tracheal and partially developed xylem elements; *C*, Meristematic Zone; *S*, Secretory Zone.

I will now pass on to the extra-cambial region in the stele of the *Lepidodendron* from Dalmeny. This stem is referred to in Professor Weiss' paper, but it is dealt with rather more fully by Dr. Scott, who has published a figure in his "Studies in Fossil

Botany[1]" illustrating the structure, as seen in a transverse section, of the tissue between the secondary xylem and the inner edge of the region, which is described by Mr. Hill and myself as the secretory zone. In Dr. Scott's figure the tissue immediately beyond the secondary wood is labelled phloem ("ph"); this is a zone about twelve cells in width; beyond this 'phloem' one of the large leaf-traces occupies the rest of the figured portion of the section. The Dalmeny stem is fortunately preserved in wonderful perfection, and by means of transverse and longitudinal sections (figs. 1 and 2) it is easy to make out the structure of the tissues between the xylem and the outer edge of the secretory zone. The tissue which Scott designates phloem is the same as that described as the meristematic zone in the original account of the stem[2], and shown in figures 1 and 2, *C*; the latter designation I believe expresses its true function. A few of the elements next the outermost secondary xylem are shown by longitudinal sections to be partially developed thin-walled tracheids (figs. 1 and 2, *T*); the active region

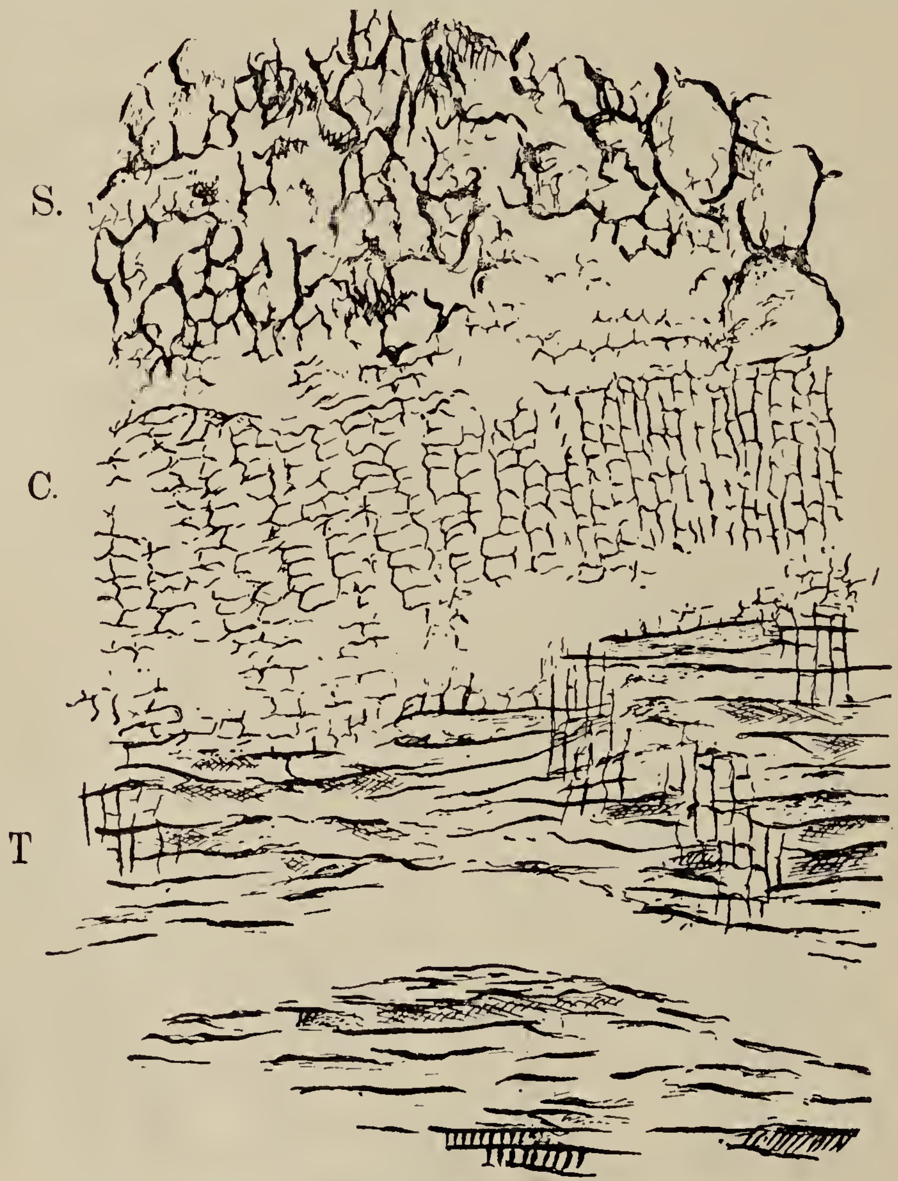

Figure 2. *Lepidodendron Wunschianum.*
Longitudinal Section. *T*, small tracheal and partially developed xylem elements; *C*, Meristematic Zone; *S*, Secretary Zone.

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[1] Scott, 1900. Fig. 52, p. 131.

[2] Seward and Hill, 1901, p. 914; Pl. II., fig. 10, *cm*, Pl. III., figs. 16 and 19 *cm*.

of the meristem-band, both in this stem and in *Lepidodendron fuliginosum* does not abut directly on the thicker walled tracheal elements, but it is separated from the wood by a few layers of cells. Beyond the unlignified tracheids, occupying the innermost portion of Scott's phloem, there are several layers of very delicate and rather flattened cells which make up the rest of the 'phloem' zone; these cells appear in longitudinal section (fig. 2, *C*) as very short elements with a depth somewhat less than their tangential diameter as represented in Scott's figure. This tissue in fact is a homogeneous band of short thin-walled cells, in which the formation of new cell-walls was in active progress when the plant was killed; the structure is essentially distinct from that of typical phloem and there are no elements which can be compared with sieve-tubes. Scott's "phloem zone" corresponds in position with the band of tissue in which Weiss recognises the cambium in *Lepidodendron fuliginosum*, while the phloem of the latter author is represented in the Dalmeny plant by a zone which lies beyond the limits of Scott's figure. Both observers agree in considering that I am in error in my view that we have not as yet discovered any typical phloem in *Lepidodendron*, but they apply the term phloem to two distinct tissues, the 'phloem' shown in Scott's figure is my meristematic zone, while that so named by Weiss is my secretory zone. The great breadth of the meristematic zone, as shown in the Dalmeny stem (figs. 1 and 2, *C*), is one of the peculiar anatomical features of the genus; the narrow cambium of recent plants was represented by a broad band which may be compared with the meristematic region of *Dracæna* and a few othe genera. Beyond the meristem band in the Dalmeny stem we find a tissue (figs. 1 and 2, *S*), distinguished by the irregular and disorganised character of the elements and by the occurrence of tangentially elongated or oval spaces, which is not included in the area figured by Scott. This band, shown at *S* in figs. 1 and 2, is certainly identical with that which I have called the secretory zone in *Lepidodendron fuliginosum*[1], and which Weiss designates phloem. The identity of this tissue (secretory zone) in the two species may be readily recognised by a comparison of Pl. II., figs. 9 and 15 *Sc.*, Pl. III. fig. 16 *Sc* in the published description of the Scotch stem[2] with text-figures 2, 3 and 5 and Pl. III., figs 3 and 4 and Pl. IV., fig. 12 in my paper on *Lepidodendron fuliginosum*[3].

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[1] Seward, 1899. Figs. 2, 3 and 5, *S*, Pl. III., figs. 3 and 4, *S*; Pl. IV., fig. 12.

[2] Seward and Hill, 1900.

[3] Seward, 1899.

I have so far entirely failed to discover any evidence of the existence of a tissue which can be called secondary phloem in Lepidodendroid stems. The broad meristem-zone in the Dalmeny stem is succeeded externally by the secretory zone, which exhibits no signs of additions made to it by cambial activity.

Dr. Scott[1] has expressed the view that the cambium in *Lepidodendron* did not produce much secondary phloem; I am inclined to go further and to express the opinion that true secondary phloem has not been recognised. This apparently one-sided activity of the meristem zone suggests a comparison with *Botrychium Virginianum*, which is described by Dr. Jeffrey[2] as characterised by the absence of secondary phloem.

It is impossible to deal adequately with the various points connected with the question of phloem without unduly extending the length of this article, but I wish to emphasize the need for further information as to certain anatomical features of the genus *Lepidodendron*. Dr. Scott has also drawn attention to some points connected with the cambium which require explanation, and he so far agrees with me in stating that "typical phloem, consisting of delicate elongated elements, cannot always be recognised, even in the best-preserved specimens."[3]

The position for which I have contended may prove to be untenable, but the facts at present available appear to me to support the opinions already expressed, *viz.* (1) *Lepidodendron* did not possess a cambium-layer of the same type as that of most recent plants, (2) that the tissue, which from its position might be designated phloem, did not exhibit the characters usually met with in that tissue, and (3), that the formation of secondary stelar tissue was chiefly, if not entirely, confined to the secondary xylem.

The nature of the tissues in *Lepidodendron* which corresponded to the cambium and phloem of recent plants is by no means definitely settled; and my object in writing these notes is not merely to justify my previous statements, but to call the attention of those interested in the study of fossil plants to some of the anatomical and physiological questions on which further information is needed.

[1] Scott, 1900. P. 142.

[2] Jeffrey, 1897. "The Gametophyte of Botrychium Virginianum. *Trans. Canad. Instit.*, vol. v., pt. ii., p. 284.

[3] Scott, *loc. cit.* p. 142.

A REVISION OF THE CLASSIFICATION OF THE GREEN ALGÆ

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(*Continued from page* 24.)

IV. Phacoteæ.

Body as in Chlamydomonadeæ, but with a *thick solid wall which* at the escape of daughter individuals *separates into two valves* (sometimes obvious during vegetative phase).

Reproduction as in Chlamydomonadeæ.

Genera.

1. *Pteromonas.* Seligo.
   Body with closely adherent wall projecting laterally as two wings.

2. *Coccomonas.* Stein.
   Body ovoid with hard, outstanding, often four-angled wall.

3. *Phacotus.* Perty.
   Body ovoid with a sculptured calcified outstanding lens-shaped wall, consisting of two loosely-connected valves, which separate at escape of daughter individuals.

[Among the unicellular motile forms two interesting but apparently isolated and little-known types should be mentioned. *Gloeomonas,* Klebs, has a body of the *Chlamydomonas*-type, but has numerous parietal rounded or elongated chromatophores and no pyrenoids; also a mucilaginous investment outside and distinct from the ordinary cell-wall. Vegetative division as in *Chlamydomonas.* Gamogenesis unknown.

Cylindromonas, Hansgirg, has an oblong-cylindrical body with a thin cell-wall and bearing a single flagellum at the anterior end; there are two star-shaped chromatophores, each with a central pyrenoid, and enclosing a nucleus between them, as in the Desmid *Cylindrocystis.* Vegetative division into 2-4 daughter cells within the mother cell-wall.]

V. Volvoceæ.

Body a *motile cœnobium* of Chlamydomonadine cells, sometimes united by protoplasmic threads, and nearly always embedded in a mucillaginous investment, through which the flagella project, and by their combined lashing give the cœnobium the power of locomotion. Cells all equivalent and capable of division to reproduce the species, or in the highest forms differentiated into (1) purely vegetative cells which have lost the power of division and (2) reproductive cells which alone can divide to propagate the species.

Agamic reproduction either by division of all the cells of the cœnobium to form as many daughter-cœnobia, or, in the highest forms, by similar division of certain reproductive cells (*parthenogonidia*).

Gamogenetic reproduction known in several genera. In the lower it takes place by the division of all the cells of the cœnobium into iso- or anisoplanogametes, in the higher by the formation of antherozoids and eggs, which in the highest genus are developed respectively from special *androgonidia* and *gynogonidia*.

[The forms belonging to this group exhibit a strikingly complete and wide-ranging progressive series of stages in the evolution of reproductive and vegetative characters:—(1) the gradual development of anisogamy from isogamy, culminating in perfect oogamy; (2) a gradual increase in the number of cells and a corresponding increase in the size of the cœnobium, associated in the highest forms with the differentiation of purely vegetative from reproductive cells, a differentiation which involves the evolution of a true *soma* or mortal body and the consequent appearance of natural death as a regular recurrent phenomenon.]

Genera.

§Cœnobium of equivalent cells, all capable of reproductive division.

1. *Spondylomorum.* Ehrenberg.

Cœnobium of sixteen loosely-connected ovoid cells arranged in four alternating tiers. No common investment. Each cell with a closely adherent wall, and four flagella attached to the broad end. Gametes unknown.

2. *Gonium.* Müller, 1773.

Cœnobium plate-like, of four or sixteen oval or slightly polygonal cells connected by protoplasmic processes and arranged in one plane, surrounded by a common mucilaginous investment. Flagella of all the cells on one surface of the plate. Gametes unknown. Resting cells (? zygotes) typical. Germination indirect.

3. *Tetragonium.* West and West.

Cœnobium as in *Gonium*, but always of four cells. Tips of flagella alone vibratile.

4. *Stephanosphæra.* Cohn, 1852.

Cœnobium of one to (typically) eight ovoid cells arranged in a circle round the equator of the spacious spherical or oval investment. Cells with several stout radiating protoplasmic processes. Flagella penetrating investment equatorially. Isogametes spindle-shaped, conjugating within the investment, to form zygozoospores.

(to be continued).

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DESCRIPTIVE MORPHOLOGY.—PHYLLOTAXIS.

By A. H. Church.

On attempting to construct a morphologically accurate descriptive account of any given flowering plant, which shall be something more than the curiously inept description still often given by systematists as a sufficient guarantee of specific rank, one is abruptly brought face to face with a whole series of problems due to the inadequacy of the terminology which has been handed down for generations as the traditional language of the science; and nowhere is this more obvious than when dealing with floral structures; so many expressions which are in almost daily botanical use being purely conventional and admitting of no scientific definition whatever. Whether one considers terms based on erroneous conceptions of the structure of the adult flower by botanists who were entirely ignorant of developmental processes, drawn from the writings of Linnaeus, De Candolle and Jussieu; or even the floral diagrams of Wydler and Eichler, one is constantly tempted to absorb purely conventional standpoints as actual facts: for example, what strictly scientific conception even now defines the limits of *perigyny* and *epigyny*; or again, where is there any strict evidence whatever that "Sepal No. 2" of the characteristic quincuncial calyx of pentamerous flowers really is mathematically median posterior?

It is this difficulty of constructing for oneself, to say nothing of obtaining elsewhere, a good intelligent and intelligible description or diagram of even the commonest flower,—one need go no further than the Buttercup for a type—that lies at the root of the present unsatisfactory nature of Elementary Botany. It is clear that the subject must be approached with an entirely unprejudiced, and preferably unorthodox mind; and in so dealing with the construction of a plant shoot as a stem bearing leaves, that is to say, an axis and its appendages, the first step toward the attainment of such correct plant description will be found in the accurate presentation of the problems of leaf arrangement or *Phyllotaxis*.

The study of Phyllotaxis is so closely bound up with the History of the Spiral Theory that it is often necessary to point out that spiral phyllotaxis still exists in the vast majority of vegetative shoots, whether one accepts any Spiral Theory or not. Because the Spiral Theory of Schimper completely failed to explain the phenomena of the comparatively rare case of Dorsiventral Symmetry, it does not follow that all conceptions of spiral growth are to be thrown overboard, and that one must accept the dictum of Sachs that there is "no general law which can be formulated for the arrangement of organs on a parent axis." Not only is spiral symmetry a perfectly definite phenomenon, but it becomes increasingly clear that it for some reason actually represents the phylogenetically primitive type of growth; and though exception may be taken to the view that all centrically symmetrical types of construction are necessarily derived from spiral growth-forms, no one will be disposed to deny that the case of dorsiventral flower-shoots is always phylogenetically a secondary phenomenon, and that here as in dorsiventral vegetative shoots every transition to a more and more perfect attainment of this special type of symmetry is observable. The general law which controls the distribution of plant members must certainly include these special cases; but in its primary significance it must be founded on the most widely distributed case.

The discussion of the elimination of the Spiral Theory of Schimper from modern morphology, with which it is still closely interwoven, for want of something better, in every elementary text-book, demands the consideration of the different standpoints of the old morphology and the new with regard to the plant as an object to be scientifically described.

To the older botanists, the morphologists of the Eighteenth Century, and so long in fact as Botany remained dominated by the doctrine of Constancy of Species, the subject of morphology presented a very simple ideal. So long as every species was regarded as a definite creation, and every individual member of the species the mere working out of a replica of the parent, morphology dealt solely with adult structures. The study of form became restricted to the formal account of the framework of the adult organism, its fully matured stem, leaves, flowers and fruit; all developmental stages represented immaturities whose form was unessential.

The whole question is after all one of standpoints, and once this 'adult' standpoint of older observers is clear, the exact significance of their further observations and deductions is rendered obvious, Similarly the adult plant remains to the present time that of the systematist and descriptive writer.

In considering, for example, the arrangement of foliar members on the shoots of adult plants, the first and most obvious arrangements were described by such terms as opposite, whorled, alternate (Sauvages, 1743), while the descriptive work of Linnaeus showed little advance; the great majority of leaf arrangements, now classed as spiral, being still included under the term *Dispositio sparsa*, or *sine ordine* (1751).

The founder of what has long been known as the Spiral Theory was Bonnet (1754), who first defined a spiral arrangement; Bonnet's observations form the basis of all theories of Phyllotaxis, and in justice to him, the exact significance of his views requires to be clearly stated. Bonnet's system related solely to adult structures or long leafy shoots, he had nothing to do with buds; he determined what is still known as the "$\frac{2}{5}$ spiral," in which the sixth leaf is inserted exactly over the first of a spiral series which makes two complete revolutions of the stem. With the aid of a mathematician, Calandrini, he formulated a definite and logically correct geometrical conception of a helix with parallel screw-thread winding round the cylindrical stem, thus spacing out leaf members of equal size at equal intervals. This mathematical conception just like any other mathematical proposition was arranged to fit certain definite *facts*; if these facts held, so would the mathematics, if other facts were included the mathematical proposition would require to be modified Bonnet knew sufficiently well that buds did not agree with this construction, but as above indicated, he had nothing to do with buds, which when fully grown would give his helix on the adult cylindrical shoot.

On the basis of Bonnet's spiral an enormous edifice of beautifully precise nomenclature was erected by Schimper and Braun (1830-1835); the fractional formulae of the "$\frac{2}{5}$" type were extended so as to include a considerable range of new ratios from the Fibonacci summation series 2, 3, 5, 8, 13, etc.; these numbers being the ones most commonly found in the plant; while other series were designed in order to include formations which did not come under this rule. The terms 'genetic-spiral,' 'divergence-angle,' 'orthostichies,' 'parastichies,' were introduced, and these still comprise the familiar terminology of the text-book; but the spiral remained the same helix proposed by Bonnet. It is not, however, always pointed out in these text-books that descriptive morphology was here really still concerned solely with adult structures, the definition of an adult part being that it has stopped growing. It refers that is to say, to a mathematically ideal construction which quite possibly is never absolutely attained in the living plant› although on adult cylindrical axes, as in the case of some Cacti the approximation is perfect to the eye, and even within the error of very small measurements.

Bonnet's spiral thus only holds, and was intended only to hold as a mathematical conception for this very special case. A helix with parallel screw-thread demands equal members or members equally spaced; in such cases true orthostichies become possible in a spiral system. The elaborated spiral system of Schimper and Braun is thus mathematically perfect, as the representation of a special case of adult plant construction; and so long as the adult plant is considered the sole object worthy of scientific discussion this elegant and precise system of nomenclature will remain unrivalled for all descriptive purposes. It does not, however, explain anything, and something more than mere description has always been the aim of the new school of Botany, which may be dated from the time of Schleiden (1842), Hofmeister, Von Mohl, Nägeli and Sachs.

As the doctrine of Constancy of Species slowly gave way to theories of Evolution; and the leaven of such ideas as were presented in Goethe's Theory of Metamorphosis of Leaves, and the philosophical discussions of growth, development and heredity by the eminent botanist and naturalist Lamarck, gradually permeated the scientific world; the more intimate acquaintance with the minute structure of developing organs which led to the discovery of the growing substance of plants by Von Mohl, also produced a clearer conception of the plant body as a growing mechanism (Schleiden, Nägeli).

Just as the adult body was the theoretical ideal plant of the older morphologists, so a growing body became the type plant of the new morphologist, as seen in the growth of the members, growth of the axes, growth of the whole individual, its reproduction and the growth of the race; while the adult structures yielded place in theory as they do in practice to ever newly developing members. The whole attitude of the botanist with regard to the plant world thus became altered and entirely revolutionised; but the corresponding change was not simultaneously effected in the descriptive nomenclature previously built up under the old regime.

To Hofmeister and Sachs, the phyllotaxis formulae of Schimper and Braun, when approached from the standpoint of the development of lateral members, were naturally found wanting. They did not explain or agree precisely with the facts of ontogeny, and Sachs expressly denounced the Spiral Theory as a mode of view gratuitously introduced into the plant, and phyllotaxis formulae as mere playing with the mathematical properties of numbers. That Bonnet's mathematical conception was, from the modern standpoint, gratuitously introduced, is obvious. Every mathematical conception as applied to the plant must necessarily be equally gratuitous; but it was never intended to do more than represent a theoretically ideal adult condition. The fallacy appears to have been introduced by Schimper himself, and remainded unnoticed by his followers, in that they did not grasp the fact that having accepted Bonnet's spiral, they were now including the case of all visible systems, growing or not; while Bonnet, in equal ignorance of protoplasmic growth, dealt solely with adult structures which had ceased growing on the attainment of a uniform specific bulk.

That a mathematical conception which was based on the postulate that the lateral members were equal in volume or equally spaced would not hold for developing members which present a gradated sequence in bulk, space and time, appears to have been entirely overlooked. Similarly any view which attempts to adopt the Schimper-Braun conventions to explain the facts of development is open to a fundamental error: a remarkable example being seen in Schwendener's "Dachstuhl" Theory, in which somewhat hypothetical forces of Contact-pressure were supposed to alter phyllotaxis formulae in all cases planned after the helix theory of Bonnet.

The error lying at the root of all theories of spiral phyllotaxis is so far clear; it was the old story of putting new wine into old bottles, the Schimper-Braun theory collapsed without being replaced by a new one, and all attempts at patching on the part of Schwendener have proved futile. What is really required is, after all, only what should have been put forward fifty years ago, namely a new mathematical conception founded on the new mathematical data afforded by the transition of the morphological standpoint from that of adult construction to that of *growing systems.*

There can clearly be no objection to the application of a mathematical conception in itself; everything in nature is capable of mathematical expression if the conditions are only sufficiently well known; the difficulty is to select the fundamental conception which may afterwards be modified as new factors are introduced into the equation.

The method of application of such a view is again clearly indicated: just as Bonnet and Calandrini postulated an ideal adult structure, so it becomes necessary, now that growth and development are assumed to be the foundation of all views of morphology, to postulate a certain ideal condition for a growing system.

A given plant need not show ideal growth, any more than it may be expected to show an ideal adult phase; but a definite standpoint is thus taken up, which comes into line with modern conceptions of the structure and development of living protoplasm, and this admits of future modification as our knowledge becomes increasingly exact. The value of a mathematical proposition depends entirely on the initial premisses; the point therefore remains to determine what mathematical premisses can be established as the basis of a growing system composed of axis and lateral members. Bonnet's system was perfect for the adult construction it was alone intended to summarise; the case of a growing shoot presents a much greater degree of complexity, and a certain ideal condition may therefore be deduced as a starting-point.

Just as in the consideration of the Newtonian laws of motion, the purely abstract and mathematical conception of uniform motion precedes that of varying motion, so the growth of a mass of protoplasm by interstitial development throughout its whole substance may, in the simplest case, be conceived as a uniform growth expansion taking place around a hypothetical central point, the "growth-centre," and proceeding at a uniform rate radially in all directions, with the result that the protoplasmic mass presents the phenomenon of a uniformly expanding sphere. Resolving such a solid sphere along planes passing through the centre, the plane projection of a section would be plotted geometrically as a circle the area of which may be divided indefinitely into a series of similar figures, in the simplest case small quasi-squares formed by the intersection of radii and concentric circles. In such a circular mesh-work of squares, any curve drawn in a constant manner through the points of intersection of the radii and circles is a spiral, the tangent to which makes equal angles with every radius vector, that is to say, it is an equiangular or logarithmic spiral. Contemplation of such a figure shows at once that log. spiral curves with the straight line and circle as limiting cases are the sole curves of uniform growth expansion. Any morphological theory of spiral growth, including spiral phyllotaxis, which is based on a proposition involving growth, should therefore be based on a *logarithmic spiral* on a plane surface; and not on a helix winding on a cylinder, which, carried on to a plane as a spiral with equal screw-thread, would become a spiral of Archimedes (Bravais). In its application to phyllotaxis, therefore, the logarithmic spiral represents a second mathematical conception as applied to growth phenomena; and as far as the living and admittedly irregular growing plant is concerned, it would no doubt be as difficult to prove by actual measurement as Bonnet's theoretical helix. But the standpoint is changed, it now becomes possible not only to deal with uniformly growing systems and deduce mathematically their special properties, but also to draw them and see them, as it were, grow on paper. Similarly, once the properties of systems exhibiting uniform growth have been ascertained, it may become possible by adding secondary conditions, to study the possibilities of varying rates of growth, and thus it becomes conceivable that the irregular growth of a living body may ultimately be as closely approximated in terms of mathematical formulae, as for example the erratic path of a comet, if the gain to botanical science should be at all commensurate with the labour expended.[1]

Botanic Garden, Oxford, *Feb. 1902.*

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[1] *Cf On the Relation of Phyllotaxis to Mechanical Laws*—A. H. CHURCH.
Part I.—*Construction by Orthogonal Trajectories.*—Sept. 1901.
Part II.—*Asymmetry and Symmetry*, Jan. 1902.

210 pp. and over 80 figures. Williams & Norgate, London and Oxford.

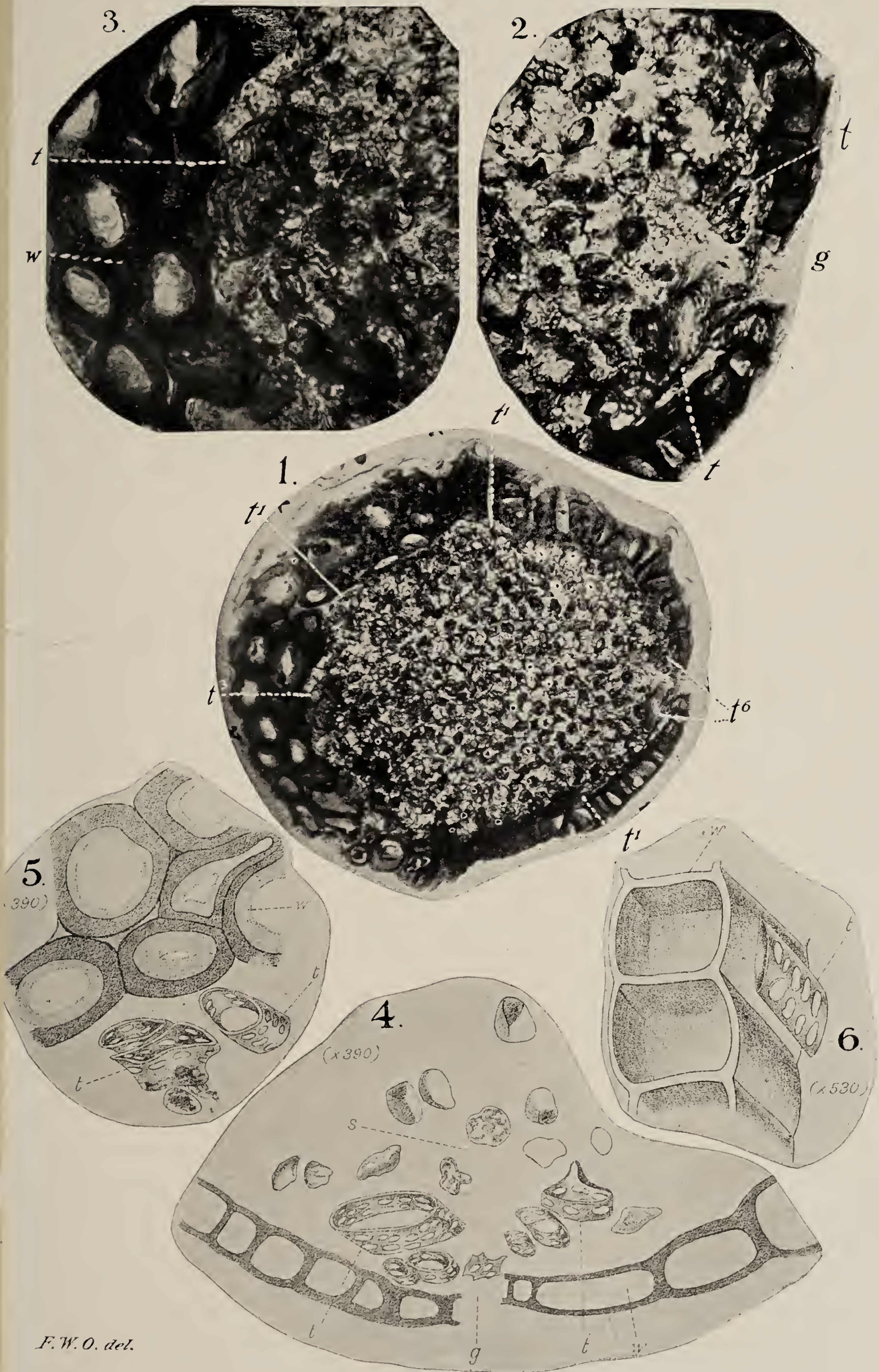
ON THE MECHANISM WHICH IS CONCERNED IN EFFECTING THE OPENING AND CLOSING OF TULIP FLOWERS.

By J. Bretland Farmer, F.R.S.,
Professor of Botany in the Royal College of Science, London.

IT is a well-known fact that the flowers of the Tulip, in common with those of many other plants, are able to open or close according to the circumstances in which they happen to be situated. Thus when brought from a cold into a warm room the closed flowers will speedily expand, but will again close on renewed exposure to cold air.

It has been said that these movements of the perianth leaves (which for the sake of brevity may be termed petals) of the Tulip are due to the prevalence of epinastic and hyponastic conditions of growth, and that in this way the opening and closing respectively of the flowers are to be explained. It is perfectly true that Tulip flowers normally continue to grow for a considerable time after they may have first expanded, but it does not necessarily follow that this fact is to be in any way directly connected with the movements in question. It may indeed be reasonably doubted whether the rate of growth is sufficiently rapid to account for the alteration, especially in the case of that consequent on *lowering* the temperature.

The phenomena might, on the contrary, be referable to the agency of a localised irritable tissue situated towards the outer or inner face of the petals. If the cells of such a tissue were capable, on appropriate stimulation, of altering their size or shape to an extent greater or less than are the cells of the adjacent tissues under similar circumstances, opening and closing movements would certainly occur. Such a mechanism might justly be compared to that which effects the corresponding changes in the positions of the leaf-lobes in Dionaea. In this plant, as is well known, the movements depend immediately on a difference in their relation to water existing between the cells of the upper and lower surfaces respectively. The former on stimulation readily part with water, and hence the still turgid cells at the lower surface then cause a closure of the lobes. In the quiescent expanded condition this turgor of the lower cells is balanced by that of the upper cells, and the lobes are thus forced to diverge from each other.



F. W. O. del.
W. Tams Phot
Swan Electric Engraving Co

As a matter of fact there is good evidence to shew that in the perianth leaves of the Tulip there exists, on the outer face of each, a tissue comparable to that in the Dionaea leaf, and that it is capable of readily undergoing changes in the condition of the turgescence of its constituent cells, and thus is able to bring about the movements under consideration.

If a section, which must not be too thin, be cut down the median line of a petal taken from a fairly young flower, and then be placed in water, the uninjured cells become turgid. And as the section becomes more or less strongly curved, it is clear that the cells on the outer side of the curve have expanded more than those on the inner side. It will be observed that this curvature is always such as would effect the closing of a petal still attached to the plant. The curvature is most striking near the base of the petal, but it may also involve the more apical region. If the turgid section be now transferred to a rather strong plasmolysing solution, *e.g.*, 3—4% KNO_3 it will be seen, after a few moments, to straighten itself rapidly; that is a movement will be executed in the sense of causing the petal to open. These opening and closing movements can be repeated on the same preparation a large number of times. It appears then that there exists on the outer face of each perianth leaf, and more especially in the region where the petal is naturally curved, a layer of active cells which are able to alter their state of turgescence, or at any rate their size, more readily and effectively than the cells which form the more internal tissue layers, and that it is to the agency of these cells that the opening and closing of the flower is to be ascribed

It still however remains to be proved that we are dealing with an *irritable* tissue, and not with a more proximate mechanical effect of the water or salt upon the cell walls. If a section which is lying in water, and hence exhibits a strong (closing) curvature be transferred to alcohol, it is killed and fixed in the curved condition. On placing it afterwards in *either* water *or* in the salt solution, it speedily becomes relaxed, and straightens out; thus shewing that its previously curved appearance was directly related to the life and activity of the protoplasm of its cells, and to the increased size of those on the outer face under circumstances which permitted the attainment of a maximum degree of turgescence.

The anatomical relations of the tissues of the perianth leaves are well adapted to facilitate rapid changes of curvature. The intercellular spaces are specially obvious in the tangential direction, and the cells in adjacent tangential planes are commonly connected across the spaces by glove-finger like unions. In this way a certain amount of shearing action and other displacements are provided for, whilst at the same time damage to the cells themselves is avoided.

The chief points in this note may be thus summarised:—

1.—The opening and closing of Tulip flowers is independent of growth and is regulated by a special mechanism.

2.—The mechanism consists of a sheet of cells near the outer face of the petals which are capable of altering their size, *either* on account of a greater readiness to acquire and part with water (according to the condition of stimulation) as compared with the cell-layers interior to them, *or else* owing to a greater range of extensibility on the part of their cell-walls as compared with the walls of the cells interior to them.

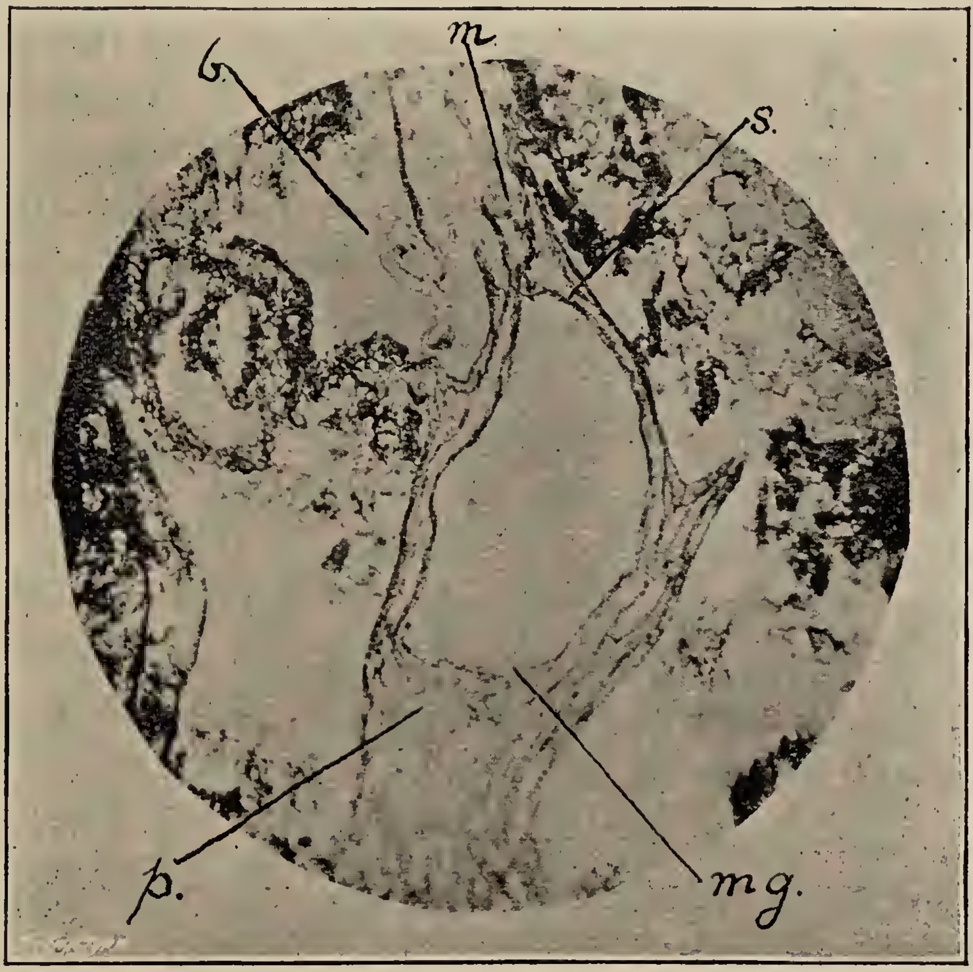
3.—The anatomical relations of the parenchyma cells to each other, and the distribution of the intercellular spaces, are such as readily admit of the occurrence of the movement, whilst minimising the risks of attendant lesions.

A NEW LYCOPODIACEOUS SEED-LIKE ORGAN.

IN the second number of this Journal appeared a review of Dr. Scott's memoir on *Lepidocarpon.* The present preliminary note to a fuller paper which I hope soon to publish, is to announce the discovery of an analogous structure from the Lower Coal Measures.

In some slides prepared by Mr. J. Lomax, from the Ganister Beds of Dulesgate, Lancashire, and sent by him in May, 1901, to Professor F. W. Oliver, who placed them in the hands of Dr. Scott, there were observed megasporophylls, some in transverse section and some in radial and horizontal section. From these it could be demonstrated that the lamina bore a large ligule and a megasporange, both of which were entirely covered in, except at the apex, by a velum or integument. One megaspore with a thin wall, like that of *Lepidocarpon*, was found in each megasporange. The lamina extended right and left and to the apex as a thin lamella, one cell thick. The microsporophylls, which have since been found, also possess a large deep-seated ligule and thin border, but the microsporange has no integument. These structures are always found in association with a very peculiar type ot vegetative structure in Hough Hill as well as in Dulesgate material. Hence it has been suggested by Dr. Scott on these three grounds, (*a*) the leaf-border one cell thick, (*b*) the position and structure of the ligule, and (*c*) the association with the said vegetative organs, that these integumented sporangia may be the reproductive organs of *Miadesmia membranacea*, a plant described and named by Bertrand in his paper "Sur une nouvelle Centradesmide," Association française pour l'Avancement de la Science, 1894, p. 588. Unfortunately, when Bertrand wrote, the reproductive organs were not available.

MARGARET BENSON.



Text-Fig. 3.—Photograph of a nearly radial longitudinal section of a megasporophyll. *m*—Micropyle. *b*—border of lamina in transverse section. *p*—Pedicel of sporange. *mg*—wall of megaspore. *s*—Sporange wall.

ON A VASCULAR SPORANGIUM FROM THE STEPHANIAN OF GRAND 'CROIX.

[With Plate I.]

By F. W. Oliver.

In the course of an investigation into certain seeds contained in the well-known silicified 'magmas' of Grand 'Croix many fossilised fragments other than those forming the main subject of that inquiry have necessarily come under my observation. These include numerous fern-sporangia of varying affinity and preservation, for the most part detached, though in occasional instances showing continuity with the vegetative organs. In one instance a transverse section of a detached sporangium was obtained which revealed an organization of more than passing interest The facts of its structure, which are novel and perhaps unique, give rise to the conjecture that we have in this sporangium a point not without morphological signification, and this quite apart from any confident attribution of the sporangium in question to its systematic position —which indeed for the present must remain a matter of opinion.

The preparation which forms the subject of the present communication showed a transverse section of a sporangium, the wall of which possesses a lining of unmistakeable tracheal elements. This section is represented in photograph 1, Pl. I., taken directly from the object. In outline the section is not quite circular, the diameter which coincides with the plane of symmetry slightly exceeding that at right angles to it. The dimensions are .65 mm. × .53 mm. The wall of the sporangium is unequally developed on the two sides. Whilst for about half its perimeter the wall consists of a single layer of relatively small rectangular cells, its other half is two, and, at places, three cells deep, and the cells of this side are larger, thicker walled and rounded. This broad indurated band represents the annulus here, and suggests a comparison with the sporangium of *Botryopteris forensis*, B.R. which has been fully figured and described by Renault[1].

The interior of the sporangium appears filled with a mass of contracted and collapsed spores; the less deformed of these have an average diameter of .02 mm. Lying between the wall and the sporogenous mass is an interrupted ring of tracheal elements.

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[1] Ann. des Sci. Nat. (Bot.), sér. vi. vol. i. Flore fossile d'Autun et d'Epinac, pt. ii., p. 47

These tracheae are fairly thin walled and exhibit well-marked pittings of a reticulated type. It has been possible to recognise five groups of these tracheae adjacent to the sporangial wall and distributed at intervals, as represented by *t*, *t* in photograph 1. The largest number found in any group was six (t^6)—close to the broken middle point of the thin side of the sporangium (*g*), whilst against the annulus at t^3 the number was three, elsewhere generally fewer than three (the number in each case is indicated by the figure following the reference letter *t*).

Owing to their slight displacement most of the tracheae are seen a little obliquely, a fortunate circumstance, as it permits of the details of their thickening being studied. The high power photographs 2 and 3 and figs. 4, 5 and 6 give these details. Photo. 2 and fig. 4 represent the group of tracheal elements abutting on the fracture in the thin part of the wall (*g*), fig. 5, a group from the opposite side of the sporangium with a portion of the indurated sporangial wall (*w*). The oval pits are numerous and shew a very delicate bordering. The largest element (*t* in fig. 4) has a diameter of .045 mm. The tracheal elements were evidently delicate stuctures and it is not improbable that they were originally more numerous than is actually indicated by the number of those preserved in this specimen. At places they occur quite flattened against the wall (as at *t*, fig. 6), so that they may have formed during life a continuous lining to the sporangium. I attribute their preservation in this case to the early mineralisation of an immature sporangium. As the block of spores ripened and distended the sporangium the tracheae would be unrecognisably crushed against the wall. It is not possible to say definitely from inspection of this specimen whether the elements were tracheides or vessels, as they are shown only as short segments.

Though the position occupied by these tracheal elements corresponds with that usually associated with a tapetum, it is not possible to make any statement as to their origin, owing to the relatively advanced developmental stage of this sporangium. Were the data available, it would be interesting to know with what layers of the sporangium the tracheal zone is associated in development. Whether, like the endothecium of an Angiospermic anther, it arises in common with the tapetum, or whether some other relation obtains. In view of the unexpected complexity of the sporangium here described, attention might perhaps be profitably devoted to such immature Botryopteridean and other sporangia as may be available.

As I have already said, this sporangium suggests a comparison with *Botryopteris.* I turn therefore to the Botryopterideae in the first instance with a view to determining how far the ascertained facts of their sporangial structure favour a reference of my sporangium to this group.

Zygopteris, Corda. Here the sporangium is large, being 2.5 mm. long by 1.3 mm. across its longer transverse diameter. The wall in Renault's figures[1] consists of a single cell-layer of well preserved cells with two indurated bands (the annulus) passing down the two opposed faces. A second layer or membrane is usually shewn retracted from the wall and enclosing the spore mass; Grand 'Eury[2] figuring a similar form (*Schizostachys frondosus*) represents the wall as of several layers.

Solms-Laubach[3] conjectures "that the inner layers were destroyed in Renault's specimens, and his figures show a sac-like envelope inclosing the spores, which I can only suppose to be a crushed cell layer." D. H. Scott[4] in reproducing Renault's figures regards the sac-like envelope as a possible tapetum. A point of great interest is recorded by Renault[5] in the statement that the pedicel of the sporangium in *Zygopteris* is traversed by a flattened, bi-polar, vascular band which extends to the base of the sporangium, being accompanied by a tissue which he regards as phloem. The spores of *Zygopteris* have a diameter of .08 mm.

Botryopteris dubius, B.R.—The sporangia of this plant have been fully described and figured by Renault[6]. The walls of the sporangia were relatively massive and consisted of several series of cells. In the best preserved specimens two layers were distinguishable in the wall:—an outer layer three or four cells deep, limited externally by an epidermis; and an inner, some three cells deep, the elements of which were elongated in the sense of the chief axis of the sporangium. There was an indurated band (annulus) passing down one side of the sporangium. The dimensions of the sporangium and of the spores are essentially the same as those given above for *Zygopteris.* In his later writings Renault[1] recognises *B. dubius* as a *Zygopteris*, though in a note in his *Zygopteris* paper[2] he had expressed a doubt as to the possibility of such a reference. I am unaware whether the evidence upon which this change of opinion is based has been published. Whilst agreeing with *Zygopteris* in the position, form and dimensions of the sporangia, *B. dubius* seems to have but a unilateral annulus, whilst in the complexity of its wall it much surpasses that which has been described for *Zygopteris.*

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[1] Ann. des Sci. Nat. (Bot.), sér. vi., vol. iii., pl. i., figs. 1 to 3.

[2] Flore carbonifère du dép. de la Loire, p. 201, and tab. xvii., *d* and *d*'. This author comments on the thickness and complexity of the wall, which he states to be formed of an outer cellular and an inner fibrous layer. He suggests a comparison with the pollen-sacs of *Cycas*.

[3] Fossil Botany, Eng. Edn., 1891, p. 150.

[4] Studies in Fossil Botany, p. 287.

[5] Flore fossile d'Autun et d'Epinac, pt. ii., p. 43.

[6] Ann. des Sci. Nat. (Bot.), sèr. vi., vol. i., pl. x., fig. 24 and pl. xi., figs. 25, 26, 27.

Botryopteris forensis, B.R.—The sporangia are smaller than in either of the foregoing, the length of the sporangium being 1.5—2 mm., its diameter .7—1.0 mm., whilst its spores attain a diameter of .06—.07 mm. The wall is described as being two-layered,[3] *i. e*, an outside limiting layer one cell thick, enlarged on one side to form the annulus, and a thin-walled, often indistinct, lining.

Of the forms just detailed our sporangium approaches most nearly in dimensions to *B. forensis*, but its spores have a diameter of only one-third (.02 mm. as compared with .06—.07 mm.), a disparity perhaps explicable in view of the immature condition of the sporangium and the collapsed condition of the spores. With *B. dubius* it has a point of contact in the lining of elongated cells which that sporangium possesses. Finally, the little vascular bundles which Renault has traced into the pedicels of *Zygopteris* render the assumption that this sporangium may have possessed a vascular coat not a very hazardous one. Indeed if *B. dubius* be really a *Zygopteris* with a well preserved wall, the elongated cells of the lining may have been tracheal in nature, a remark likewise applicable to the inner layer of *Schizostachys.* Hence it would appear as not wholly improbable that a tracheal layer in the sporangial wall of Botriopterideæ may have been a common character. As yet the evidence is lacking, and in any case can only be expected to accrue slowly from occasional and exceptionally preserved specimens.

But there is another group, the Marattiaceae, that should not be omitted from consideration as affording a possible resting place for our sporangium. Of the numerous Pecopteroid and other fructifications that have been attributed to this order, several show the rudiments of an annulus. Such a form with unmistakeable

[1] Flore fossile d'Autun et d'Epinac, pt. ii., p. 42.

[2] Ann. des Sci. Nat. (Bot.), sèr. vi., vol. iii., p. 23.

[3] Flore fossile d'Autun et d'Epinac, pt. ii., p. 54.

annulus is *Sturiella*, Weiss (*Pecopteris intermedia* of Renault), the sporangia of which Solms-Laubach[1] says are especially distinguished "by the presence in their wall of an apical group of abnormally thick-walled cells which extend some way down on the outer side of the sporangium; these cells have quite the appearance of an annulus." But in addition to this character there is a supposed peculiarity of the cells of the annulus, which Renault places on record[2] in his original description of the specimen. He says "Les cellules qui composent le connecticule [*i. e.* the annulus] sont irrégulières; leurs parois fortement incrustées présentent des stries transversales ou des réticulations (fig. 10)." The figure in question[3] is a somewhat tangential longitudinal section of a sporangium, and in the position at which an inner layer to the wall (did such exist) would be exposed, three spindle-shaped cells are shewn with transverse striate markings. Without examining the original preparation, I should, however, hesitate to put any interpretation on these appearances other than that sanctioned in the passage quoted from the text.

Whilst admitting the possibility that my sporangium might be placed near this last type—should it bear the interpretation just suggested—I am inclined to associate it with the Botryopterideæ, indeed, it may be a sporangium of *Botryopteris forensis*, B.R., revealed in a new light owing to a fortunate accident of fossilisation. Such an attribution would receive a certain measure of corroboration from the fact that throughout the small block from which the preparation was obtained, the very characteristic equisetiform hairs of *B. forensis* are sparsely scattered. That the dimensions of the cross-section (.65 mm. × .53 mm.) are somewhat below the normal for this species may be due to the fact that our section is not across the broadest portion of the sporangium, or possibly, it may not yet have attained its full dimensions. The smallness of the spores (.02 mm. diameter) is also susceptible of explanation in view of their immaturity and of the contraction which they have undergone.

The biological significance that may be attached to the tracheal mantle may well be that of an organ for the conveyance to the maturing spores of adequate supplies of water. That such a provision has not been more generally recognised is not on the whole surprising in the case of fossil Ferns, for these tracheae are very delicate structures and liable to obliteration on the maturing of the sporangium. In the fossil seeds of Gymnosperms—*Stephanospermum*, and others—the presence of tracheal elements at the periphery of the nucellus of the seed, passing from the chalaza to the pollen–chamber, was a common feature. Not improbably, in these cases, adequate physiological requirements connected with important functions were operative and led to the retention of the tracheal tissue to a late stage in development.

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[1] Solms-Laubach, Fossil Botany, Eng. Edn., 1891, p. 145.

[2] Renault, Cours de botanique fossile, tom. iii., p. 123.

[3] Loc. cit., plate xxii, fig. 10.

The presence of vascular tissue in close proximity to the sporangium in Pteridophytes generally is not very common. In the sporangiophore of *Sphenophyllum Dawsoni* a small bundle runs to a point just short of the sporangium, where it ends in a somewhat bulb-like enlargement consisting of reticulated tracheides. Something of the same kind is indicated in *Helminthostachys* and *Botrychium*, and occasionally in *Lygodium*,[1] whilst in *Tmesipteris* little bundles run within the margin of the synangial septum. Amongst the Cycads I find that strands of well-developed spindle-shaped tracheides penetrate the pedicels of the pollen-sacs in *Bowenia spectabilis*[2], where they may be found reaching up to within a distance of six cells of the actual sporogenous mass. To these instances may be added that of the pollen-sacs in *Cordaianthus Penjoni* and *C. Saportanus*, to the base of which delicate vascular ramifications penetrate[3]. Finally, presenting some analogy with the foregoing we have certain instances amongst the Amentales[4]—*Casuarina*, *Castanea* and *Corylus*—in which spindle-shaped tracheides occur right amongst the sporogenous tissue of the nucellus, though in a manner suggesting that they are vestigial in nature.[5]

But the chief interest in the observation here put on record seems to lie in the recognition in a sporangium of one of the palaeozoic Ferns of a condition which is recognised as normal in so many of the fossil gymnosperm seeds. If my conjecture that the sporangium belong to one of the Botryopterideae be confirmed,

[1] Scott, *loc. cit.*, p. 289.

[2] I am indebted to my friend Mr. A. C. Seward, F.R.S., for kindly placing at my disposal a series of sections through a cluster of pollen-sacs of this plant.

[3] Cf. Renault—Structure comparée de quelques tiges de la Flore Carbonifère. Pl. xvi , fig. 14, *g*, and Pl. xvii., fig. 3, *f*.

[4] M. Treub, in Ann. du jard, bot. de Buitenzorg, vol. x. M. Benson, "Contrib. to the Embryology of the Amentiferae." Trans. Linn., Soc. 2nd ser., vol. iii., Bot. S Nawaschin, Bull. de l'Acad. Imp. des Sc. de St. Petersbourg, 1899, vol. x., No. 4, p. 375.

[5] M. Benson, loc. cit., p. 421.

then the observation has a certain, if unimportant, bearing upon current views regarding the phylogeny of the Cycadales. Scott[1] in his interesting discussion of the Botryopterideae correlates the French and English representatives of the group and shows how they are to be regarded as representing the more simply organised stock of the primitive Ferns, the polystelic Marattiaceae being the more complex. On purely anatomical grounds the Botryopterideae seem to have a claim to affinity with the stock from which the Cycadofilices arose, and in our present lack of knowledge concerning the manner of fructification of this group, the suggestion that the vascularity now found in the sporangium of an apparent Botryopteridea may be homologous with the tracheal tissue which we recognise as so characteristic and well marked a feature in the early Gymnosperms does not appear wholly unreasonable. Whilst in our sporangium, and in the Botryopterideæ generally perhaps, if my surmise be well founded, the tracheal sheath served the simple end of conveying water to the ripening spores (perhaps under xerophilous conditions), in the early Gymnosperms it has undergone a marked advance and specialisation, in harmony with the modified fate and enlarged functions of the macrosporangium; and at the same time has come to discharge functions more complex than the mere supply of water to a sporogenous tissue.

University College, London. *Jan.*, *1902.*

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[1] *Loc. cit.*, pp. 277 and 507.

EXPLANATION OF THE PHOTOGRAPHS* AND FIGURES ON PLATE I.

Illustrating F. W. OLIVER'S paper on "A Vascular Sporangium."

PLATE I.

Photograph I.—Transverse section of the sporangium (× 110).

t[1] solitary tracheal elements.

t[3] and *t*[6] groups of three and six tracheal elements.

Photograph 2.—View of the tracheal group *t*[6] (of photo. 1) under higher magnification (× 290).

t-t tracheal elements (six in all).

g gap in wall.

Photograph 3.—View of the tracheal group *t*[3] (of photo. 1) under higher magnification (× 290).

w thick part of sporangial wall.

t tracheal group.

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*I am indebted to Mr. W. Tams, of Cambridge, for the trouble he has taken in obtaining the photographs reproduced here.

Fig. 4.—Tracheal group shown in photo. 2 (× 390).
t-t tracheal elements.
s spores.
w wall of sporangium.
g gap in wall.

Fig. 5.—Tracheal group shown in photo. 3 (× 390).
t-t tracheal elements.
w wall of sporangium.

Fig. 6.—Tracheal element flattened against wall of sporangium (=t^1 at bottom of photo. 1) (× 530).
t tracheal element.
w wall, here one cell thick.

A REVISION OF THE CLASSIFICATION OF THE GREEN ALGÆ

BY

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AND
A. G. Tansley,
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(*continued from page* 48.)

5. *Pandorina.* Bory, 1824.

Cœnobium of 16 (rarely 32) pyramidal cells closely packed within a spherical investment, the apices of the cells nearly reaching the centre of the sphere, the broad ends bearing the flagella approaching the surface. Gametes 16-32 from a single cell, very variable in size; conjugation mainly promiscuous, but the largest (rudimentary female) relatively passive, not conjugating *inter se.* Germination of zygote indirect.

6. *Eudorina.* Ehrenberg, 1832.

Cœnobium of 32 (rarely 16 or 8) spherical cells rather far apart in a single layer within a spherical or oval investment. Anisogamy by union of reduced yellow pear-shaped swarmers (antherozoids) which are produced 64 from a cell, with eggs which scarcely differ from vegetative cells. Germination direct.

7. *Eudorinella.* Lemmermann, 1900.

Cœnobium of 8 spherical cells, as in *Eudorina*, but in two parallel planes; viewed perpendicularly the four cells in each plane form a square and alternate with the four cells in the other. Reproduction unknown.

8. *Platydorina.* Kofoid, 1899.

Cœnobium of 16 or 32 spherical cells arranged in a single layer, and forming a horse-shoe-shaped plate, with a slight left-handed spiral twist. Mucilaginous investment produced at posterior (heel) end into 3 or 5 symmetrical blunt processes. Flagella of successive cells alternately projecting upon either face. Development by compression of a primitive cup-shaped cœnobium, so that the cells of the two faces intercalate. Gametes unknown.

§§ Cœnobium with a definite *soma.*

9. *Pleodorina.* Shaw, 1894.

Cœnobium of 32, 64 or 128 spherical cells in a single peripheral layer within a spherical or elliptical investment. Somatic (purely vegetative) cells occupying the anterior pole of the cœnobium, the remaining (gonidial) cells larger, alone capable of reproductive division. Gametes unknown.

10.—*Volvox.* Linnæus.

Cœnobium of about 200 to 22000 spherical or polygonal cells usually connected by stout or by fine protoplasmic processes, arranged in a single peripheral layer within a spherical investment. The enormous majority of the cells are somatic. Parthenogonidia 1 to 16 (usually 8), larger than vegetative cells. Androgonidia similar to parthenogonidia, few or very numerous, each forming a transitory cœnobium which may be plate-like with few, or spherical with numerous antherozoids. Antherozoid a reduced elongated swarmer with sharply pointed anterior end and green or yellow chromatophore. Gynogonidia few, larger than vegetative cells. Oospores smooth or sculptured. Germination direct. Sexual colonies monœcious or diœcious, sometimes possessing parthenogonidia.

[The organisms belonging to this genus exhibit a remarkable culmination of the cœnobiate evolution of motile cells of the *Chlamydomonas*-type. While retaining the cell-type of that primitive form, *Volvox*, by the differentiation of most of the cells of its body as a true soma, has reached a stage of evolution comparable with that of the Metazoa, and only attained along the other lines of algal descent by forms far on among the higher families. In *Volvox* we find realised the utmost potentialities of the structural plan of the motile spherical cœnobium, and on its own lines this remarkable form may fairly be said to present us with the unique spectacle of a "perfect organism."]

(*b*) PLANT-BODY NON-MOTILE DURING THE DOMINANT PHASE. CELLS UNINUCLEATE MULTIPLYING BY VEGETATIVE DIVISION.

[In this section are included all those forms of the non-motile Protococcoideæ in which repeated vegetative division is a conspicuous feature of the life-cycle. The separation of these forms into the two families of Tetrasporaceae and Pleurococcaceae is artificial, and was originally made to turn strictly on the presence or absence of zoospores. A number of small natural groups of genera can be made out within both these "families" but knowledge does not yet enable us to bring the whole of the forms into any satisfactory natural arrangement. We therefore retain the old artificial distinction, though not strictly, and indicate some of the natural groups within the "families."]

Fam. II. Tetrasporaceae.

Plant-body rarely unicellular *never motile when adult* though sometimes ciliate, usually *consisting of the products of successive vegetative divisions united* by the more or less mucilaginous remains of the mother-cell walls *to form a colony*, often of fairly definite form. Cells always rounded or oval and mostly showing the chlamydomonad-type of organisation, usually lacking however, the eye-spot. Reproduction typically by *zoospores* arising from any of the cells of the body and often also by conjugation of *isoplanogametes*.

**Ciliatae.*

Individual cells generally provided with two flagella, but the whole colony immotile.

[The flagella found in this group are usually extremely long, being mostly imbedded in the mucilaginous matrix of the colony. They appear to be functionless and have indeed been often overlooked. Only in *Physocytium*, the simplest member of this group, have they the chlamydomonadine appearance and this apparently indicates the phylogenetic origin of the group.]

Genera.

1. *Physocytium.* Borzi.

Colony globular, attached by two fine threads which seem to be derived from the flagella of a zoospore which has anchored itself by means of them. The cells within the colony, few in number, and irregularly clustered, arise by division of this zoospore body; each cell has usually two short flagella. Isogametes.

2. *Apiocystis.* Nägeli.

Colony pyriform, firmly attached by the narrow end; interior of very thin mucilage. The cells are distributed in a single layer below the surface, and each may or may not have two long cilia. Zoopores and gametes known.

3. *Tetraspora.* Link.

Colony a floating crumpled membrame of indefinite form. Cells biflagellate distributed in a single layer and grouped in fours.

[The long flagella of the cells are obvious in the very young colonies, but not easily detected in the thick mucilage of the old ones. Thuret figured the flagella in 1850 (Ann. Sci. Nat., Bot., sér. 3. tom. xiv, pl, 21, fig. 7) but several subsequent writers have ignored them.]

4. *Stapfia.* Chodat, 1897.

Colony vermiform of dense mucilage cells in a single layer below the surface. Flagella conspicuous, but entirely imbedded in the mucilage.

***Dendroideæ.*

Colonies consisting of oval cells grouped to form more or less tree-like clusters by the united but not confluent remains of the mother-cell walls.

[This group seems also to be derivable from the *Chlamydomonas*-type, and in the simplest genus, *Chlorangium*, only a few sessile generations become aggregated before the cells all revert (as zoospores) to the motile condition.]

5. *Chlorangium.* Stein.

Colony a widely diverging branched system of only a few segments. Chloroplasts two, lateral (a departure from the chlamydomonad-type possibly evolved by halving).

6. *Echallocystis.* Bohlin, 1897.

Colony of very closely compressed branchings, the successive mother-walls largely superposed.

7. *Prasinocladus.* Kuckuck, 1894.

Colony of oval clustered cells attached by short mucilaginous stalks. Chloroplasts at first several in a cell-fusing to one later.

****Filamentae.*

Colony taking the form of a branched or unbranched mucilaginous cylinder in which the cells are imbedded as a central series, usually at some distance from one another.

8. *Radiofilum.* Schmidle, 1894.

Colony an unbranched cylinder. Cells in close contact, with their long axes at right angles to the axis of the cylinder.

9.—*Hormospora.* Brébisson.

Colony as in *Radiofilum* but the long axes of the cells are parallel to that of the colony and the cells are further apart.

10.—*Hormotila.* Borzi.

Colony a cluster of mucilaginous cylinders branching in any direction. Cells large and globular, cylinder narrower between the cells

11.—*Hauckia.* Borzi.

Colony dichotomously branched, the successive members attached to the older ones by short mucilaginous stalks. Cells oval, cylinder of uniform width.

*****Chlorosphaereae.*

Cells living singly or loosely associated in an indefinitemncilaginous investment.

12.—*Chlorosphaera.* Klebs, 1883.

Cells spherical with a stellate or reticulate chromatophore. usually containing several pyrenoids. Transverse cell-walls are formed in vegetative division, which occurs in all directions in space. Zoospores are formed, 8 or more from a single cell. Akinetes also occur. Gametes unknown.

The affinities of the following genera are doubtful:—

13. *Dictyosphaerium.* Nägeli.

Colony a globose mass of few or many spherical cells which are united in fours by the thong-like remains of the successive mother-cell-walls. The cells are at some distance from one another, the interspaces being filled by their respective mucilaginous envelopes. Under certain conditions the cells may exist free, singly.

14. *Tetracoccus.* West, 1892.

Colony of irregularly clustered groups lying in an indefinite free-floating mucilaginous mass and each composed of four cells, lying in one plane and united by delicate filaments.

15. *Ineffigiata.* West & West, 1897.

Colonies of 2-8 rather large cells, very various in shape and bearing irregular spines by which they are aggregated.

16. *Botryococcus.* Kützing.

Colony a free-swimming or attached botryordal mass, consisting of a cluster of oval cells each with a dense mucilaginous investment.

17. *Dactylococcus.* Nägeli.

Colony consisting of a very few apiculate thin-walled cells which are loosely united to one another at their points of contact. No obvious mucilaginous investment.

Fam. III. Pleurococcaceæ.

Plant-body either *unicellular or a mucilaginous indefinite colony or a true cœnobium;* very rarely a filament *(Stichococcus)*, never ciliate or motile. Cells of various shapes but frequently not far removed from the chlamydomonad-type of organisation.

Reproduction typically taking place solely *by vegetative division.* Zoospores and gametes typically absent.

[Certain genera placed in this family are known to produce zoospores, and in other cases they probably occur, but this has not been allowed to prevent their inclusion in any group to which they seem to belong naturally.]

*Gloeocystiaceæ

Body a mucilaginous colony, fixed or free-swimming, of definite or indefinite shape, cells dividing in two or three directions in space united by mucilage derived from the mother-walls. Zoospores described in some forms.

Genera.

§Colony indefinite.

1. *Glococystis.* Nägeli.

   Colonies indefinite, mucilage shewing concentric layering round the cells or cell-groups.

2. *Palmella.* Lyngbye.

   Colonies indefinite, mucilage not shewing concentric layering.

3. *Schizochlamys.* A. Braun.

   Cells scattered without order in mucilage, groups of 2 or 4 often remaining together. Cell-wall splits into 2 or 4 equal parts at division. Zoospores recorded.

§§Colony definite.

4. *Palmodactylon.* Nägeli.

   Colonies finger-shaped, simple or branched, sometimes diverging from a common centre. Cells spherical. Zoospores described.

5. *Palmodictyon.* Kützing.

   Colonies rounded, few-celled, connected into an anastomosing network.

6. *Palmophyllum.* Kützing.

   Colonies flat, leaf-like, of considerable size, divided into fan-shaped lobes.

(to be continued).

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SOME RECENT WORK ON HYBRIDS IN PLANTS.

By V. H. Blackman.

THE study of hybrids* has been for a long time a field of work very much neglected by botanists, and it is only in quite recent years that interest has revived in the subject. Yet investigations on the crossing of plants were once, in pre-Darwinian days, prosecuted with the greatest vigour, as the works of Kölreuter, Gärtner, Naudin and others show. The two first-named observers practically devoted their lives to the subject of the artificial production of crosses between various forms of plants. In spite however, of the large amount of time and labour expended in these researches, no general conclusions seemed forthcoming. The form of the hybrid was found to vary within very wide limits, so that it might be almost exactly like one of its parents (the false hybrids of Millardet), or it might be almost exactly intermediate between the two, but there seemed no clearly recognisable law relating any of the characters of the hybrid to those of the parents. Again, in very many cases there was shown to be a certain degree of sterility in the hybrids produced by crossing forms which are commonly accepted as " species," but that this sterility is in universal contrast to the perfect fertility of "varieties" when crossed, a view strongly held by both Kölreuter and Gärtner, is not supported by the evidence. Kölreuter was compelled to reduce ten accepted species to the rank of varieties owing to their being quite fertile together. It is also well known to horticulturalists that many hybrids between "species" are perfectly fertile together under suitable conditions and can be grown in large numbers. It was also noticed that in many cases the hybrids were inclined to revert, often very quickly, to their parental characters, but this is in no sense a general law.

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*The term "hybrid" is in the present state of our knowledge incapable of exact definition. It used to be applied only to the result of a cross between different species, but is now more generally used (as in this paper) for the result of a cross between forms sufficiently dissimilar to be considered as belonging to distinct species, races, varieties etc.; as, however, none of these categories are at present capable of exact definition, the term hybrid itself is not definable.

The apparent barrenness of the field in general conclusions was partly due to the method of work; with one brilliant exception to be mentioned later, the hybrids were considered too generally, attention was not sufficiently concentrated on certain special characters in the parent, and the behaviour of these investigated in the hybrids and in later generations; further, the results were not usually treated in a statistical manner. It is this absence of general scientific results and, as Bateson has pointed out, the veering of interest in other directions with the acceptance of the Darwinian theories, that have led to the neglect of the study of hybridisation of plants. That the subject is of the greatest importance no one can doubt, and already results of no slight value have been obtained. It is being more and more clearly recognised that if any real insight is to be gained into the laws of heredity and the all important question of "species" the subject must be attacked not only from the systematic and statistical, but also from the experimental side. Now the crossing of two plants of different characters and the exact study, in all aspects, of the resulting hybrids and their descendants is one of the most obvious experimental ways in which light can be thrown, not only upon the way in which the characters are inherited, but also on the relation of the various characters, the sum of which constitutes what we call a species, a variety, etc.

When De Vries, who had been led to a study of hybrids in relation to his theory of Pangenesis (according to which the whole character of an organism is built up of different entities), published in March, 1900, a paper entitled "Sur la loi de disjonction des hybrides," in which he laid down general laws for the relation of the characters of the hybrid to that of the parent, it seemed that at length the study of hybrids was to throw considerable light on the wider question of the laws of heredity. In the following month the results were more fully stated in a further paper, but there he makes the surprising statement that he has discovered that the laws he had deduced were not only not new, but had been fully stated and even explained in the same way so far back as 1865 by Gregor Mendel. This earlier paper was, however, published in a somewhat obscure journal and had been generally overlooked until it was disinterred by De Vries, and curiously enough also by

Correns and Tschermak at about the same time. Mendel investigated the behaviour of the hybrids between the various races of *Pisum sativum* his was the first thorough statistical study of hybrids, and as his methods of work were so convincing, his results so striking, and of such general importance that they open up wide avenues for further work, his observations are certainly worthy of close attention.

Peas were selected by Mendel for his experiments, because they are easily protected from foreign pollen, are naturally self-fertilised, and because the hybrids are quite fertile, and so can easily be raised in large numbers though numerous generations. He crossed only races which had constantly differentiating pairs of characters, and he selected the following seven pairs of characters for investigation, (1) form of ripe seed, whether round and slightly wrinkled or irregular and deeply wrinkled, (2) colour of cotyledons, whether yellow or green, (3) colour of seed-coat, whether grey (or grey brown) or white, (4) form of pod, whether inflated or constricted, (5) colour of unripe pods, whether light to dark green or vivid yellow, (6) position of flowers, whether borne laterally on the axis or in a terminal cluster, (7) length of stem, whether long (6-7 feet) or short ($\frac{3}{4}$-$1\frac{1}{2}$ feet).

The first striking point in Mendel's work was that the hybrids produced by any of the crosses exhibited none of the above characters in an intermediate form, but in all cases one or other of the differentiating characters of any pair was transmitted unchanged, and all the hybrids followed one character. This character Mendel calls the *dominant* one, while to the other he applies the term *recessive.* In the list given above of the pairs of characters investigated those found by Mendel to be dominant in nature are placed first, the recessive second. Thus the hybrids, whatever their origin, all showed a seed of round form with shallow depressions, they were never of irregular or intermediate characters; all the cotyledons were yellow in colour, never green or intermediate; the seed was always grey (or grey-brown), etc., etc.

The dominance of the special characters was very obvious in the hybrids themselves, but the great value of Mendel's work lies in the fact that he made clear the exact behaviour of the differentiating characters in futher generations produced from the hybrids by self fertilisation. This he investigated not only in the simplest case in which hybrids were produced from races that differed in only one pair of characters, but also in more complex cases where the crossed races differed in several pairs of characters.

Dealing first with the simplest cases in which the parent races differ in one character, such as the form of the seed or the colour of the cotyledon, it was found that in the second generation (the original hybrids themselves being considered the first generation) individuals appeared with the recessive character only, and these were always almost exactly one quarter of the whole number of the second generation ; in other words, the hybrids exhibiting the dominant character gave rise to plants which had either the dominant or the recessive character, and these always in the proportion of 3 to 1. Mendel found that this ratio held for all the characters investigated and no transitional forms were observed Plants with the recessive and plants with the dominant character were often produced from one and the same hybrid. The variations were very great in different individuals, thus one plant would produce seeds which were nearly all yellow in the cotyledon while another would produce seeds with yellow and seeds with green cotyledons in about equal numbers; when, however, a large number of plants were considered the relative number of dominant and recessive forms in the second generation was always very close to the ratio of 3 to 1.

Continuing the study further it was found that the forms which exhibited the recessive character in the second generation were pure* forms, for they produced offspring in the third generation with the recessive character only, thus one quarter of the forms of the second generation are pure recessive forms. Of the forms with dominant characters (which represent three-fourths of the second generation) one-third are obviously pure forms, for in the third generation they produce offspring with only the dominant character; the other two-thirds are obviously of hybrid nature, for though themselves exhibiting only the dominant character, they produce offspring with both dominant and recessive characters and that in the same proportion as in the second generation, namely, 3 to 1. It is thus clearly shown by a study of the third generation that the original hybrids by self fertilisation produce offspring (the second generation) of which one quarter are pure forms with the recessive character, one quarter pure forms with the dominant character, and only one half hybrid forms which are shown to be of mixed nature by their offspring. By a study of the next generation it was found that, similarly, the hybrids of the second generation produced offspring of which only half were hybrids, the others being pure forms exhibiting the dominant and recessive character in equal numbers. A study of further generations produced by self-fertilisation gave exactly similar results.

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*Those forms which both in themselves and their offspring exhibit a character or characters derived from one original parent only are considered "pure" forms, since they no longer show that they are of mixed origin. Similarly those forms which, in themselves or their offspring exhibit characters derived from both original parents must still retain their mixed nature, and so are considered as hybrids,

If A be taken to represent the dominant character, and a the recessive, then Aa represents the case in which the two are combined, and A + 2 Aa + A will represent in proper relative proportion the three classes of forms in the progeny of either the original or later hybrids produced by crossing races bearing the differentiating characters A and a. It is clear that as only half the offspring of the hybrids of one generation are hybrids in the next the number of hybrids will in a few generations become a very small proportion of the total progeny of any given hybrid. The gradual dying out of the hybrid character confirms the observations of Gärtner, Kölreuter and others, that hybrids are inclined to revert to their parental forms.

The accompanying table shows at a glance the numerical relation of the various classes into which the offspring of a single hybrid fall in the first few generations, each plant being supposed to bear only 4 fertile seeds. The terms A and a are used as above. The forms Aa and A are of course externally indistinguishable.

PARENTS.	HYBRID AND OFFSPRING.				
	I. Gen.	II. Gen.	III. Gen.	IV. Gen.	V. Gen.
a		1 a ...	4 a ...	16 a ...	64 a
			2 a ...	8 a ...	32 a
				4 a ...	16 a
					8 a
	Aa	2 Aa	4 Aa	8 Aa	16 Aa
					8 A
				4 A ...	16 A
			2 A ...	8 A ..	32 A
A		1 A ...	4 A ...	16 A ...	64 A

It is clear that in such a scheme in the fifth generation there are only sixteen hybrids out of a total progeny of 256. The proportion of the three classes a, Aa and A is 15 : 2 : 15 in this generation. Further a general formula can be obtained showing that in the next generation the relative number in the three classes is $2^{n-1}—1 : 2 : 2^{n-1}—1$.

The phenomena described in relation to the offspring of the hybrids are so definite and comparatively simple that there is probably some simple cause at work leading the hybrids described above to produce regularly three classes of offspring in the strict numerical proportion of 1 : 2 : 1. From a study of the hybrids with a single pair of differentiating characters just described and from that of the more complex cases where the hybrids possess two or more pairs of differentiating characters Mendel was led to the conclusion that in respect of the pairs of characters which he investigated, the gametes[*] (sexual cells) of the Pea hybrids transmit only one or other of the characters, but not both; in other words, in relation to these characters the gametes themselves are pure, not hybrid, in nature. This hypothesis, assuming that the various kinds of male and female gametes are produced on the average in equal numbers, fully explains the definite and regular behaviour of the hybrids and their offspring.

If A and a be used as above then there are four possible combinations of the gametes of the hybrid Aa when self-fertilised.

♀A × A♂	♀a × A♂
♀A × a♂	♀a × a♂

The first combination will give rise to a pure dominant form, and the last to a pure recessive form; the second and third combinations will produce similar hybrid forms. If the two kinds of gametes occur in equal numbers it is clear that the chances are equal for the occurrence of any of the four combinations, and as two of the combinations produce similar hybrid forms there will be two hybrid forms for every pure dominant and pure recessive form, and A + 2 Aa + a will express exactly the relative proportion of their occurrence. Further, all the first three combinations will produce forms with the dominant character and only the last recessive, so that the dominant forms will bear to the recessive a proportion of 3 to 1.

The hypothesis that the gametes of the hybrids transmit only one character of the pairs in question explains then so completely the striking numerical results obtained by Mendel in his experiments that there is a very strong *primâ facie* case for believing that it is the correct explanation. The theory is also supported by the behaviour of the offspring of the hybrids in the more complex cases where several pairs of differentiating characters are combined together. In the case where the hybrids unite two pairs of differentiating characters (A a and B b) it is clear that the number of possible combinations of the gametes of the hybrid is given by the combinations of the two series:—

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[*] Mendel uses the terms egg and pollen cells.

A + 2 Aa + a and B + 2 Bb + b.

The number of different combinations so produced is nine, and of these nine combinations four should each occur once, four should each occur twice and one should occur four times in every 16 plants. In the actual experiment the number of different classes of forms which appeared was nine and they occured in the proportion deduced above from the theory. Similarly when races with three pairs of differentiating characters are crossed, twenty-seven classes are to be expected from a combination of the series:—

A + 2 Aa + a, B + 2 Bb + b, C + 2 Cc + c.

In the actual experiment twenty-seven classes of forms occurred, and that in the proportion to be expected from the theory.

Mendel attempted to put his theory to further experimental proof by crossing a hybrid, produced from parent races with two pairs of differentiating characters, with both its parents and using alternately hybrid and parent as male and female. The four series of experiments may graphically be written in terms of the gametes thus:—

(i.) ♀ A B, ♀ A b, ♀ a B, ♀ a b × ♂ A B.
(ii.) ♀ A B, ♀ A b, ♀ a B ♀ a b × ♂ a b.
(iii) ♀ A B × ♂ A B, ♂ A b, ♂ a B, ♂ a b.
(iv.) ♀ a b × ♂ A B, ♂ A b, ♂ a B, ♂ a b.

It is clear that in each of the experiments four classes of forms should appear, and that those of the first and third should be exactly like those of the second and fourth experiments. Furthermore if the several forms of male and female gametes of the hybrids are produced on an average in equal numbers then all the classes of form should occur in the same numerical proportion. All the forms which the theory demands were produced, and in approximately equal numbers.

Mendel's results have been largely confirmed by Tschermak ('00) and Correns ('00a) for Pea Hybrids, and by De Vries ('00a) in a number of cases other than Peas. It is interesting to note that De Vries seems to have arrived independently at the same view of the separation of the characters of the sexual cells, at a time when, in common with other botanists, he had overlooked the existence of Mendel's work.

The two outstanding results of Mendel's work are the law of dominance (the Prävalenzregel of Correns), and the law as to separation of the character in the gametes of the hybrid, which

Correns calls Mendel's law (De Vries' "loi de disjonction.") Slightly modified from Correns it may be stated thus—in respect of certain pairs of parental characters the hybrids produce gametes which contain between them all possible combinations, in equal numbers, of these characters, with the exception that no two characters of a pair occur together.

That Mendel's law is of the greatest importance in relation to the general laws of heredity and to our conception of the relation of characters in the organism there can be no doubt. Instead of the old idea of the necessary mixing of characters on hybridisation, held so strongly by most of the early workers on hybrids, we get a new view, as Bateson ('01) has pointed out, "that a living organism is a complex of characters of which some at least are dissociable and capable of being replaced by others. We thus reach the conception of unit characters which may be rearranged in the formation of the reproductive cells."

However great the importance of Mendel's law, there can be no doubt that the view formerly put forward by De Vries('00a,b) that this law and that of dominance holds good for nearly all hybrids is erroneous. The work of Gärtner and Kölreuter shows clearly that the law of dominance does not hold for a number of hybrids and Mendel himself recognised that it did not hold even for all the characters of Pea races. That Mendel's law has striking exceptions was shown by Mendel ('70) himself in his preliminary studies of Hieracium hybrids, in which the characters investigated obey neither the law of dominance nor do they separate in the sexual cells, for in the second generation all the offspring were found to be like their parents.

How far Mendel's law will apply to other cases of hybrids is still an open question, but in this connection mention must be made of the work done by Correns, De Vries and Tschermak, and the recent criticism of Weldon ('02) on the generality of the law.

(*To be continued.*)

ECOLOGICAL NOTES.

THE ARCTIC FLORA.

THE vegetation of the circumpolar lands presents many attractive features to the botanist who cares for the wider biological aspects of his science. In the first place the extremely unfavourable conditions of life which obtain in the very cold regions of the earth furnish the completest contrast to the circumstances which have developed the unparalled richness and diversity of tropical floras. Again, the likeness that can be traced between the arctic and alpine floras, the conditions of which are closely similar though by no means identical, forms one of the most interesting studies in comparative ecology. In common with high alpine (subglacial) vegetation, the vegetation of the tropical desert, and indeed with all plant-communities exposed to very severe physical conditions, the arctic flora is characteristically an "open" flora, the individual plants usually growing some distance apart, with spaces of unclothed soil between. In such communities the plants have to struggle, so to speak, directly with inorganic nature, and only succeed in gaining a footing here and there, while the competition of plant with plant for space and light and air, a competition so enormously important in the life and evolution of the complex floras of the moist temperate and tropical areas, is largely or entirely absent. These "open" floras have a fascination of their own; to borrow an artistic phrase, they are "seen" far more easily than the confused, tangled masses of vegetation of more favoured regions, and the problem of their adaptation is a simpler one.

The fundamental features of the ecology of the arctic communites have been made clear mainly by the researches of Swedish naturalists, among whom Kjellman, Warming and Kihlman take the foremost place. Excellent accounts of their results may be found in Warming's "Plantesamfund" (1895)—German edition, "Œcologische Pflanzengeographie," translated by Knoblauch—and Schimper's "Pflanzengeographie" (1898). The latest addition to our knowledge comes from Thorild Wulff, who gives, under the title of "Botanische Beobachtungen aus Spitzbergen" (Lund, 1902), a most interesting account of some researches made on that island with the Russo-Swedish expedition in the summer of 1899.

THE TRANSPIRATION OF ARCTIC PLANTS.

The first section of Dr. Wulff's publication deals with the transpiration of arctic plants. Careful physiological investigations into the relation of plants to their environment is an essential factor in any attempt at a real understanding of the life of a plant-community, and it is Dr. Wulff's merit to have furnished us with the first series of such investigations on arctic plants relating to this particular physiological process—from an ecological point of view, perhaps the most important of all. On the whole, arctic plants belong very distinctly to the xerophilous type—they are usually clearly constructed in such a way as to diminish the amount of water evaporated from their subaerial organs, Dr. Wulff used Stahl's cobalt-paper method, and found that the time occupied in the reddening of the blue paper by a transpiring leaf placed between two pieces of the paper which had been previously dried over a spirit-lamp, gave a good rough test of the rate of transpiration from the leaf-surface. Accurate quantitative estimations were of course quite out of the question under the conditions in which he had to work. The experiments were carried out on ten representative arctic species of flowering plants, at various hours of the day and under various atmospheric conditions.

The general results showed in all cases a very feeble transpiration compared with that which obtains under favourable conditions in warmer climates. One of the most striking and interesting facts brought to light was the frequent *falling* of the transpiration-rate in relatively high temperatures (8.5–9.5°C) and correspondingly decreased relative humidity of the air, i.e. under conditions which would lead to *increased* transpiration in ordinary climates. The explanation of this phenomenon must apparently be sought in the supposition that the plants are, on the whole, adapted to transpiration at lower temperatures and with a damper atmosphere. They dare not make use, so to speak, of the conditions which favour evaporation, because their roots are unable to absorb enough water to cover the loss which would result. On the other hand, as one would expect, transpiration was very feeble when the air was nearly saturated, and at the lowest temperatures (2.5 °C). The most favourable conditions for transpiration appear to have been temperatures of about 5°C and a relative humidity of 60–70%.

There was of course no diurnal periodicity, since the sun was continuously above the horizon during the whole period—several days—within which the observations were carried out.

MYCORHIZA AND ITS SIGNIFICANCE.

In connection with Stahl's recent important work[1] on the significance of that intimate association of certain fungi with the roots of many plants known as "Mycorhiza" (now known to be a phenomenon affecting probably considerably more than half the species of the higher plants), and his theory that Mycorhiza is correlated with a difficulty of obtaining nutritive salts, with feeble transpiration, and with poverty or absence of starch formation in the leaves, it is of great interest to note, as Dr. Wulff points out (1) that a considerable number of arctic plants have Mycorhiza, (2) that of 16 species collected and investigated by him all shew marked sugar-reaction,[1] and absence or poverty of starch, and (3) as has been already shown, arctic plants have a very feeble transpiration current. Though the exact relations of these series of facts is not wholly clear, their causal connexion certainly seems indicated.

Thus the Mycorhiza-symbiosis would fall, at least so far as the nature of the soil in which the affected roots live is concerned, into two very distinct classes of cases; first, those in which the soil is largely composed of humus or leaf-mould, comparatively poor in inorganic salts, among which may be mentioned the beech and the hazel of our own woodlands; and secondly those in which the soil is quite destitute of humus and while possibly rich in inorganic salts cannot supply these freely to the plant owing to the lack of an adequate transpiration-current.

THE RED COLOURING OF ARCTIC PLANTS.

The extraordinary purity and brightness of the colours of many Alpine flowers (and the same is true of Arctic ones) is well known. The vivid colouring often extends to the whole subaerial part of the plant, the leaves and stems shewing a deep red or purple which often masks the ordinary chlorophyll-green. This is due to the presence of soluble red, purple or blue pigments in the cell-sap of various living cells of the leaf and stem, very rarely (*Eriophorum angustifolium* var. *triste*) to colouration of cell-walls; to these pigments the collective name Anthocyanin has been given. Dr. Wulff finds that the presence of this pigment is an almost universal character istic of Arctic plants. In a very interesting paper published three years ago, Dr. Overton[1], of Zurich, shewed that the development of anthocyanin in leaves was nearly always connected with a deficiency of starch and a corresponding increase of sugar (glucose); in other words, the anthocyanin, leaves are "sugar-leaves." Now, we have already seen that of 16 species cf Arctic plants taken at random, *all* shewed marked sugar reaction. We therefore apparently have in the general occurrence of anthocyanin in Arctic plants another link in the peculiar chain of their general economy. With regard to the actual position of anthocyanin in this chain, Pick[2] was of opinion that the pigments in question facilitated the passage from the leaf of the products of assimilation, and in support of this view Wulff finds that the red cell-sap is sometimes confined to special layers of cells which may be carbohydrate-conducting in the petiole and stem. In the absence of mcre exact knowledge of the chemical processes by which this facilitation is supposed to take place, it may however, be questioned whether the formation of the red or violet pigment is not primarily a direct result of the modified metabolic processes going on in the assimilating and conducting cells. An accumulation of pigment originally arising in this way may well be of use to the plant in enabling it to absorb more radiant energy, and thus to help out its rather feeble vital processes. This view of its direct utility is held by Kerner[3] and is also endorsed by Wulff in his present work.

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[1] Dr. Wulff took precautions against confounding sugar-reaction with tannin-reaction.

[1] Der Sinn der Mycorhizenbildung. Jahrb. f. wiss. Botanik, xxxiv., 1900.

RESEARCH IN BRITISH ECOLOGY.

Investigations of very difficult and fundamental problems in the ecology of plants usually raise more questions than they answer, but this is a natural occurrence in research on subjects of which our ignorance is so great, and only shews the necessity for active and determined work in all directions. As the periphery of our area of knowledge is widened, its points of contact with the vast fields which are still obscure increase in number, and this is a necessary feature of all progress. Dr. Wulff's researches are an excellent example of the kind of work that has to be done, not only on Arctic plants, but on those of plant-communities nearer home. The ecology of the British Isles is a strangely neglected field of research. On the whole, no doubt, our flora closely resembles that of North-west Germany, Denmark and Southern Scandinavia, the general features of which have been ably sketched by Warming, Krause, Graebner, and others, but in spite of the almost total absence of endemics, there are not a few interesting features of difference. And behind the general features of the distribution of plant-communities, there lie the deeper problems to which allusion has been made. It is to be hoped that both these aspects of the question will be taken up in the near future by British botanists Ecological surveying is comparatively easy and very attractive work; a knowledge of the rudiments of geology, a fair acquaintance with the species composing the flora, and quick eyes, form the most necessary equipment for the pursuit. Good maps and a camera are very desirable adjuncts. For the deeper problems, on the other hand, a high degree of training, close and long-continued study of particular problems, and access to a laboratory and experimental garden are essential.

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[1] Beobachtungen und Versuche über das Auftreten von rothen Zellsaft bei Pflanzen.—Jahrb. f. wiss Bot., 1899.

[2] Bedeutung des roten Farbstoffs bei den Phanerogamen—Bot. Centralblatt, 1883.

[3] Pflanzenleben, 1896, p. 379.

Co-operation is necessary if any considerable results are to be obtained. It is much to be desired that the surveying part of the work should be taken up by the active members of local natural history societies. A scheme could easily be organised by which they might work under some central direction, and there can be no doubt that, once initiated, the fascinating nature of the work would ensure its continuance and propagation. A committee of Section K (Botany) was appointed at the Glasgow meeting of the British Association last year, to consider the possibility of the systematic collection of ecological photographs on the lines of the admirable collection made by the Geologists' Association. We suggest that this committee should ask leave to extend its functions in the direction indicated, provided the requisite concurrence and support can be obtained from the local societies, whose co-operation would be essential to success.

THE RECENT DISCOVERIES OF PTERIDOPHYTE PROTHALLI.

OUR knowledge of the gametophyte generation of the homosporous Vascular Cryptogams, with the exception of the Equisetineæ and of the Ferns proper, has remained in a very backward condition till comparatively recently. Dr. Treub's well-known researches on the prothalli of tropical Lycopods constituted a great advance in this subject. He described[1] the prothalli of *Lycopodium cernuum, L. salakense, L. Phlegmaria, L. carinatum, L. nummularifolium* and *L. Hippuris*, and shewed that these tropical species could be assigned to two very distinct types of gametophyte within the genus, (i.) the type of *L. cernuum*, in which the prothallus is an upright green cylindrical structure with marginal lobes on the edge of its expanded summit, and autophytic, (*i.e.* doing its own assimilation by means of its chlorophyll), and (ii.) the type of *L. Phlegmaria*, which has a colourless branched cylindrical structure and is saprophytic in humus on tree trunks. Besides these there was the already partially known type of the European *L. inundatum*. In 1898 Prof. Bruchmann of Gotha published a full account[2] of the prothalli of several European species of *Lycopodium*, including *L. clavatum, L. annotinum, L. complanatum* and *L. Selago*, all of which are subterranean and saprophytic, though they turn green if cultivated on the surface of the soil, and showed that five types can be distinguished within the genus. This variety in the form and habit of the gametophyte in a single genus is a remarkable fact, in striking contrast with the great uniformity of the sporophyte, which in all known species of the Club-mosses is extremely similar in appearance and anatomy. So impressed, indeed, was Bruchmann with this diversity in the gametophytes of the different species that he proposed to separate the genus *Lycopodium* into several distinct genera according to the structure of the gametophyte, and suggested that the similarity of the sporophytes should be explained as the result of convergent adaptation. This conclusion has not, however, been generally accepted. In the same year, Dr. W. H. Lang, of Glasgow, independently discovered the prothallus of *Lycopodium clavatum* as a result of careful search in the mountains near Clova, in Forfarshire. In his account of his observations[3] he criticises Bruchmann's views and points out that in a very old and cosmopolitan genus like *Lycopodium*, the adaptation of the prothallus to various conditions of environment has very likely been an important factor in enabling the plants to maintain themselves in the struggle for existence, and that consequently the great diversity of the prothallus in different species, exceptional though it appears to be, is not surprising.

In pursuit of his researches on the gametophytes of the Vascular Cryptogams, Dr. Lang undertook, in 1900, an expedition to

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[1] Ann. du. jard. bot. de Buitenzorg, vols. iv., v., vii., 1894,-6,-8.

[2] Ueber die Prothallien und die Keimpflanzen mehrerer europäischer Lycopodien Gotha, 1898.

[3] On the Prothallus of Lycopodium clavatum.—Ann. of Bot., 1899.

Ceylon and the Malay Peninsula, with the special object of looking for the still undiscovered prothalli of the Lycopod *Psilotum*, and the remarkable Ophioglossaceous plant *Helminthostachys zeylanica.* In this quest he was very largely successful. After a vain hunt in the best localities for *Psilotum* in Ceylon, a single prothallus of unknown origin was discovered on the trunk of a tree-fern on Maxwell's Hill, in Perak (Malay Peninsula), and there is considerable evidence that it belongs to *Psilotum*,[1] though the possibility exists that it may belong to a species of *Lycopodium.* It conforms pretty closely to the type of *Lycopodium cernuum.* In the case of *Helminthostachys*, however, complete success was attained. A considerable number of the prothalli were found in a damp jungle at Hanwella, near Colombo, a locality which Dr. Lang had been led to expect would be a suitable one for his purpose. There is no doubt that the failure of more than one previous worker to find this prothallus was due to searching in dry localities, where the plant spreads by means of its underground rhizome and no prothalli are formed.

The prothallus of *Helminthostachys*, of which a full account is given in the current number[2] of the "Annals of Botany," is a brown cylindrical structure, growing by means of an apical cell and bearing sexual organs on its sides and summit, and short rounded knob-like branches covered with rhizoids at its basal end. It is subterranean and saprophytic, and, like all the known prothalli of this habit, infested with an endophytic fungus, which, like that of the leguminous root-tubercles, at first aids the plant to manufacture organic food, but is eventually killed and presumably used as food by the host.

Dr. Lang also obtained prothalli of the epiphyte *Ophioglossum pendulum* from the same locality. The fronds of this beautiful plant hang in long strap-shaped pendants from the mass of humus collected by the larger epiphytic ferns such as *Asplenium Nidus* and *Polypodium quercifolium*, and it was in this humus that the prothalli were found. The fully-grown prothallus consists of a number of cylindrical branches, radiating from a centre. There is an entire absence of rhizoids, but the surface is covered by numerous short, wide, unicellular hairs. On the sides of the branches the sexual organs are borne, and the internal tissues are inhabited by an endophytic fungus, apparently identical with that found in the roots of the sporophyte.

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[1] Lang. Proc. Roy. Soc., 1901.

[2] Lang. On the Prothalius of Ophioglossum pendulum and Helminthostachys zeylanica.—Ann. of Bot., March, 1902.

The prothalli of these two genera differ from that of *Botrychium virginianum*, as described by Jeffrey in 1897[1] and *B. Lunaria*, both of which shew a tendency to a thick flattened form of prothallus, with in *B. virginianum* the sexual organs on the upper surface.

With regard to the bearing of the gametophytic characters upon the affinities of this isolated group, the Ophioglossaceæ, the weight of evidence is distinctly on the side of a Filicinean ancestry. The apical growth, the structure of the archegonium, and the multiciliate spermatozoids (known in *Botrychium* aud *Ophioglossum pedunculosum*) may be mentioned as the most important characters connecting this family with the Filicineæ, and separating them from the Lycopodineæ, the other group with which an affinity has been suggested.

Close upon Dr. Lang's preliminary account of his discoveries came the announcement of the finding of the prothallus of the very simple Lycopod *Phylloglossum*, by Mr. A. P. W. Thomas,[2] of Auckland, N.Z.

It turns out to be of the *Lycopodium cernuum* type and lends support at once to the belief that this type is the primitive form of Lycopod prothallus, and to the view that *Phylloglossum* itself is a relatively primitive Lycopod.

Thus within five years the discoveries of the prothalli of no less than eight species, and two, if not three, genera belonging to the Ophioglossaceæ and homoporous Lycopodineæ have been announced. The curious epiphytic Australian genus *Tmesipteris* is the only type belonging to these groups of whose gametophyte, &c., we are still ignorant, if we assume that Lang's isolated prothallus is really that of *Psilotum*.

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[1] Transactions of the Canadian Institute, 1896-7.

[2] Proc. Roy. Soc. 1902.

A REVISION OF THE CLASSIFICATION OF THE GREEN ALGÆ

BY

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(*continued from page* 72.)

***Selenastraceæ.*

Body either unicellular or an indefinite colony or a true cœnobium. *Cell* of very various shape, rarely spherical or oval, often pointed at one or both ends, *very frequently reniform or semilunar,* sometimes flattened. Cell-wall typically of an inner, thin, closely-adherent membrane, and an outer, mucilaginous coat, which is sometimes produced into processes, and by which the single cells often adhere together. *Chromatophore single, parietal, often basin-shaped, but frequently occupying nearly the whole of the cell,* usually with a single pyrenoid.

Reproduction by vegetative division, typically into four cells enclosed within the mother cell-wall. The four daughter cells may either separate at once by diffluence of the mother wall, or remain together, typically adhering by their mucilaginous coats, often to form definite cœnobia. *Zoospores and gametes entirely unknown.*

[This group includes the majority of the typical Pleurococcaceæ of Klebs, and seems a very natural one. The general features of the cell-type are remarkably constant and the group can be theoretically derived from a Chlamydomonadine ancestor in which the formation of flagella has been suppressed, and the cell has become elongated and often curved. In the simplest genera the cells live singly but shew a tendency to remain connected after division. From this type more or less definite colonies seem to have been evolved in various directions. The prevalence of the crescentic form of cell is a marked feature of the group.

The name we have adopted is taken from a fairly typical genus and has the advantage of calling attention to the prevalent crescentic cell-type, as well as to the radiating structure often exhibited by the colonies.]

Series A. Cells rounded or pointed and sometimes curved; *floating freely,* either *singly, or slightly adherent* to form indefinite colonies.

7. *Dactylococcus.*[1] Nägeli, 1849.
   Cells oval or pyriform, often apiculate, single or loosely coherent by their pointed ends.

[1] This genus has generally been placed among the Tetrasporaceæ, and we followed tradition in including it among the genera of doubtful affinity belonging to that artificially defined family, but the most careful existing account denies the existence of zoospores, and assigns it characters which clearly give it a natural position among the lower members of our Selenastraceæ. We have therefore introduced it again in this place.

8. *Raphidium.* Kützing, 1845.
Cells acicular or fusiform, curved or straight, with pointed or rounded ends; usually free but sometimes united in indefinite colonies. Pyrenoid usually absent.

9. *Coccomyxa.* Schmidle, 1901.
Cells oval, often slightly curved, sometimes with narrowed ends, isolated, or in pairs or fours, embedded in mucilage. Chloroplast parietal without a pyrenoid. Reproduction by vegetative division into two or four.

[This appears to be a genus closely allied to *Raphidium* and *Dactylococcus*, but adapted to aerial life.]

Series B. Cells crescentic, *embedded in thin mucilage.*

10. *Nephrocytium.* Nägeli, 1849.
Cells reniform, occuring in ovoid groups of 2-16, the individual cells separated from one another by mucilage and the whole group surrounded by the distended mother-cell-wall, which retains a sharp contour.

11. *Kirchneriella.* Schmidle, 1893.
Cells semilunar or vermiform, occurring as a cluster within a mucilaginous investment, which soon becomes diffuse.

12. *Selenoderma.* Bohlin, 1897.
Cells semilunar, more or less widely scattered in a flat indefinite mucilaginous matrix.

Series C. Cells crescentic to spherical, united to form a *cœnobium radially symmetrical in three dimensions.*

13. *Selenastrum.* Reinsch, 1867.
Cœnobium of 4-16 crescentic cells, cohering by their convex surfaces to form an approximately centric group.

14. *Sorastrum.* Kützing, 1845.
Cœnobium centric, the cells being united at the centre by short stalks. Cells rounded to crescentic, with short spines exteriorly.

15. *Coelastrum.* Nägeli, 1849.
Cœnobium a hollow sphere, unually with intercellular gaps, composed of few or many cells which are spherical or polygonal. The cells are known to live singly in media rich in oxygen.

Series D. Cells round to crescentic, united to form a *uniseriate colony or cœnobium.*

16. *Dactylothece.* Lagerheim, 1883.
Cells oval, straight, or curved, grouped 1-4 in a linear series often embedded in mucilage. Division in one direction only.

17. *Dimorphococcus.* A. Braun, 1849.
Cells 2-8 in the cœnobium, all similar and reniform, or the internal ones oval and the external semi-lunar; usually arranged in a zigzag line.

18. *Scenedesmus.* Meyen, 1829.
Cœnobium of 2-8 (usually 4) cells in one or rarely two rows, with rounded or pointed ends. Some or all of the cells may bear mucilaginous processes, often curved. Chromatophore filling most of the cell. Cells known to be capable of living singly in media rich in oxygen.

Series E. Cells more various in form, but often flattened, and always united in fours to form *plate-like cœnobia* or syncœnobia.

19. *Tetrastrum.* Chodat, 1895.
Cells flattened pyramidal with rounded corners, grouped in fours, with apices inwards and spines on the external face.

20. *Hofmania.* Chodat, 1900.
Cells oval, each with a tapering bract-like mucilaginous appendage derived from the mother-cell-wall.

21. *Lemmermannia.* Chodat, 1899.
Cells flat, triangular, united by their edges in fours to form a square plate. On multiplication the daughter-cœnobia remain closely united.

22. *Actinastrum.* Lagerheim, 1882.
Cells elongated-oval or cylindrical, usually cohering by their ends to form flat radiating groups of four. Arrangement often irregular.

23. *Crucigenia.* Morren, 1830.
Cells of various flattened forms, united directly or by processes to form a flat plate with a central perforation. The cœnobia are usually grouped into syncœnobia with some regularity. Daughter-cœnobia arise by division of the cell contents cross-wise.

24. *Willea.* Schmidle, 1900.
Characters of *Crucigenia*, but forming an irregular plate of several hundred cells. No pyrenoid.

25. *Crucigeniella.* Lemmermann, 1900.
Cells in fours as in *Crucigenia*, but without pyrenoids. The cells divide only in the plane of the colony and the two apposed four-celled colonies thus produced soon separate.

****Phytheliaceæ.*

Plant body always floating freely, unicellular or a more or less definite cœnobium. *Cells very minute,* spherical or nearly so, sometimes with a mucilaginous envelope, *the walls bearing radiating bristles several times as long as the diameter of the cell.* Reproduction by simple division or by the division of the cell-contents into several zoospores or into aplanospores ("*autospores*") which may acquire the characters of the adult cell before or after their escape.

[We have ventured provisionally to give the above name to a well-characterised and apparently natural group of fresh-water plankton-algæ, most of which have been recently brought to light, mainly by the researches of Chodat and Lemmermann. See especially Beiträge zur Kenntniss der Planktonalgen, Hedwigia, 1898.]

Genera.

26. *Golenkinia.* Chodat, 1894.

Cells usually single, each with a single parietal chromatophore containing one pyrenoid. Cell-wall surrounded by a layer of mucilage and bearing numerous radiating bristles. Reproduction by simple vegetative division, by quadri-flagellate zoospores or by autospores.

27. *Richteriella.* Lemmermann, 1896.

Cells of the *Golenkinia*-type, but always united in cœnobia of 16 or 64 cells (smaller numbers may occur by some of the cells failing to divide) Cell-wall not surrounded by mucilage. Bristles only on the sides of the cells facing outwards, thick at the base, tapering. Vegetative division alone observed.

28. *Franceia.* Lemmermann, 1898.

Cells oval, single or united in colonies. Cell containing 2-3 parietal chromatophores and a single vacuole; wall surrounded with mucilage. Bristles long and of uniform thickness. Vegetative division longitudinal.

29. *Phythelios,* Frenzel, 1891.

Cells spherical, single, with radiating bristles of uniform thickness, a single chromatophore and no pyrenoid. Reproduction unknown.

[This genus was originally described by Frenzel as a Heliozoan. His species has not been seen again, but the genus has been adopted by several algologists as an alga, Frenzel's pseudopodia being interpreted as bristles. Recently another species has been described.]

30. *Acanthosphaera,* Lemmermann, 1899.

Cells spherical, single, with a pyrenoid cell-wall very thin, usually without mulcilage, bearing numerous radiating bristles. Lower third of each bristle thick and refractive, upper two-thirds very delicate and hyaline. Reproduction unknown.

31. *Bohlinia.* Lemmermann, 1899.
Cells oval, single, with many radiating bristles which are thickened at their bases. Chromatophores 1-2, parietal, without pyrenoids. Reproduction by autospores, bristles developed while within the mother-cell.

32. *Lagerheimia.* Chodat, 1895.
Cells single or in cœnobia of 2-8, enclosed in the mother cell-wall, ellipsoidal or cylindrical with rounded ends. Chromatophore single with one pyrenoid. Cell-wall solid, bearing bristles. Bristles tapering, each with a basal wart. Reproduction by vegetative division, bi-flagellate zoospores (?) or autospores

33. *Chodatella.* Lemmermann, 1898.
Characters of *Lagerheimia*, but bristles often numerous and with no basal warts. Reproduction by autospores.

34. *Schroederia.* Lemmermann, 1898.
Cells single fusiform, many times longer than broad, sometimes curved or spirally twisted, with a bristle at each end. Single chromatophore and pyrenoid. Reproduction by vegetative division observed.

[This form much resembles a *Raphidium* with polar bristles.]

35. *Centratractus.* Lemmermann, 1900.
Cells single, oval, bearing at each end a long hollow bristle thickened at the base. Several reticulate chromatophores with no pyrenoids. Reproduction by transverse division.

The affinities of the following genera are doubtful:—

36. *Pleurococcus.* Meneghini, 1842.
Cells spherical when isolated, typically with a single (sometimes parietal) chloroplast, with or without a pyrenoid. A transverse internal cell-wall is formed at vegetative division, and the daughter cells frequently remain together in groups of 2, 4 or more, the walls in contact being flattened by mutual pressure. Under certain conditions the cells of such groups may grow out to form short filaments.

[Very great confusion has prevailed as to the identity and life-history of the forms included in this genus. According to Chodat some species are extremely polymorphic, reproducing themselves under different conditions by vegetative division, aplanospores, zoospores or gametes, and giving rise to cells closely resembling those belonging to other genera of unicellular algæ. This is, however, denied by various other algologists.]

37. *Pilidiocystis.* Bohlin, 1897.
Cells oval, endophytic in the mucilage of Cyanophyceous colonies. Cell-wall forming a thick cap towards the surface, but hardly traceable elsewhere. From the deeper end one or two threads project downwards,

38. *Eremosphaera.* De Bary, 1858.
Cells single, spherical, unusually large, floating freely. Chloroplasts numerous, containing pyrenoids.

39. *Excentrosphaera.* Moore, 1901.
Cells single, large, spherical to elliptical or irregular. Chloroplasts numerous, angular, closely covering the wall, each containing several minute pyrenoids. Reproduction by numerous aplanospores, which escape by dissolution of part of the mother-wall.

40. *Oocystis.* Nägeli, 1855.
Cells oval, one to eight enclosed in a firm mother-cell wall. Colony floats freely. Chloroplasts many, parietal.

41. *Chlorella.* Beyerinck. 1890.
Cells spherical or slightly elliptical, minute, with a thin wall and a single parietal chloroplast, usually possessing a distinct pyrenoid.

[An alga occurring under very various conditions and frequently symbiotic.]

42. *Polyedrium.* Nägeli, 1849.
Cells of very irregular and variable polyhedral shapes, with spines and other outgrowths. The daughter-cells are at first invested with mucilage, but afterwards float freely. Chloroplast single, with a pyrenoid.

§ Cells tending to form linear aggregates.

43. *Catena.* Chodat, 1900.
Cells cylindrical, with flat ends, and joined in chains of usually four cells by the centres of the ends.

44. *Gloeotila.* Kützing, 1843.
Cells cylindrical, connected up into short filaments, with slight constrictions between the cells.

45. *Stichococcus.* Nägeli, 1849.
Cells cylindrical, existing either freely or united to form an unconstricted filament of some solidarity.

(c.) PLANT-BODY NON-MOTILE DURING THE DOMINANT PHASE, MOSTLY COENOCYTIC, NOT MULTIPLYING BY VEGETATIVE DIVISION.

[In this section are included all those forms of the non-motile Protococcoideæ in the life-history of which new cells arise only from swarmers and never by the septation of existing vegetative cells.

The majority of genera are single cells or coenocytes, but in a few the plant-body consists of a cœnobium of coenocytes. arising by the apposition of a number of zoospores.

In most of the forms which have been carefully investigated the single nucleus of the original cell has been found to divide during the growth of the cell till a considerable number is present, and the plant-body becomes a simple coenocyte.

It seems clear that it is from this section of the Protococcoideæ that the more complex coenocytic types of the Siphonales have been evolved.]

Fam. IV. Chlorococcaceæ.

Plant-body a *single cell or coenocyte of simple form*, free or epiphytic. Chromatophore nearly always a single parietal plate and containing one pyrenoid.

Reproduction only by the formation of *zoospores* in all the forms. Gamogenesis never yet observed. Vegetative division found only in palmelloid stages.

[The first three genera form a natural series which may be regarded as derived from the Chlamydomonas-type by the evolution, from its characteristic continuous succession of walled motile cells, of a type in which this sequence has differentiated into an alternation of naked motile cells (zoospores) and walled non-motile cells (the plant bodies).]

Genera.

1. *Chlorococcum.* Meneghini.
   Plant body round, coenocytic when adult, floating or attached to a substratum and then often polygonal by compression—the result of a number of zoospores having come to rest close together. Zoospores eight or more from each cell.
2. *Sykidion.* Wright, 1879.
   Cells globular or ovoid, attached singly or in clusters, nucleus always single. Two or four zoospores may arise in any cell and escape by the detachment of a special lid.
3. *Characium.* A. Braun, 1849.
   Plant body ovoid or cylindrical, erect or oblique, often beaked, attached singly by a definite mucilaginous stalk. Zoospores several in a cell, sometimes liberated by the detachment of a special lid.
4. *Dicranochaete.* Hieronymus, 1887
   Cells hemispherical, attached by the flat surface to water plants. Chloroplast single with one or several pyrenoids; nucleus single. Zoospores 4-32, liberated by the detachment of a special lid. A remarkable large, tubular richly-branched filar structure grows out from the base and spreads out above the organism.
5. *Halosphaera.* Schmitz, 1878.
   Cells very large and spherical, floating freely in the sea. Chloroplasts of numerous parietal discs; nucleus single. Zoospores many from each cell, of unusual form with flagella arising from the broad end.

[The affinities of this genus are by no means clear, but the absence of vegetative division seems to indicate its inclusion in this family.]

Fam. V. Endosphaeraceæ.

Plant-body a simple *spherical cell or a slightly branched coenocyte.*

Reproduction by the formation of *zoospores* or of *planogametes* *or* of *both*. *Zygote germinates without resting.* All the genera are *endophytic.*

[The members of this very natural family all dwell in the intercellular spaces of either water plants or plants growing in moist places, and they all persist through the winter as akinetes and not as zygotes.]

Genera.

1. *Chlorochytrium.* Cohn, 1874.

   Cells oval or irregularly rounded. Chromatophore a parietal layer round the whole cell, containing many pyrenoids. Zoospores and gametes occur. Conjugation of the latter takes place within the extruded mucilaginous inner layer of the gametangium.

2. *Stomatochytrium.* Cunningham, 1888.

   Chiefly distinguished from *Chlorochytrium* by the absence of the mucilaginous investment of the gametes.

3. *Chlorocystis.* Reinhard, 1885.

   Distinguished from *Stomatochytrium* by the chromatophore only lining part of the cell and having only one pyrenoid. Marine.

4. *Endosphaera.* Klebs, 1881.

   Cell-shape and chromatophore as in *Chlorochytrium.* Gametes occur but not zoospores.

5. *Scotinosphaera.* Klebs, 1881.

   Cell-shape and chromatophore as in *Chlorochytrium.* Reproduction by zoospores alone observed.

6. *Centrosphaera.* Borzi, 1883.

   Cells oval, occurring in the mucilaginous sheaths of blue-green algæ. Zoospores only known.

7. *Phyllobium.* Klebs, 1881.

   Plant-body probably coenocytic and forming a branched tube deep within the stems of water-plants. Chloroplast a thin parietal layer. Reproduction by zoospores and by anisogametes. A resting winter akinete is cut off in one part of the branched tube.

(to be continued).

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SOME RECENT WORK ON HYBRIDS IN PLANTS.

By V. H. Blackman.

(continued from page 80.)

Correns' (1901, A, B) recent work on hybrids between the various constant races of *Zea Mays* has led him to put forward a classification of the various pairs of differentiating characters of a hybrid. He points out that the pairs of characters fall roughly into four groups according to their behaviour (1) during vegetative development, (2) during the formation of the sexual cells. In the vegetative development of the hybrid one of the characters may be dominant, the other recessive, as in the case of many characters of Pea hybrids already described; to such a pair of characters he applies the term *heterodynamic*: or both characters may exhibit themselves in the hybrid and form a new character intermediate between those of the parents; such pairs of characters are found very commonly, and Mendel showed that they occur in *Hieracium* hybrids; to these Correns applies the term *homodynamic*. Again there are also two extreme cases to be considered in relation to the behaviour of the characters at the time of gamete formation; the characters may then be separated as described in the case of Pea hybrids; to these the term *schizogonous* (isogonous, De Vries) is applied; on the other hand the characters may undergo no separation, and such pairs of characters are described as *homoiogonous* (anisogonous, De Vries). Four types may now be distinguished, as is clear from the table below.

	VEGETATIVE DEVELOPMENT	GAMETE FORMATION.	TYPE.
1.	Heterodynamic.	schizogonous.	Pisum.
2.	Heterodynamic.	homoiogonous.	——
3.	Homodynamic.	schizogonous	Zea.
4.	Homodynamic.	homoiogonous.	Hieracium.

The first may be called the *Pisum*-type, because a number of the differentiating characters in Pea hybrids conform to this type, as Mendel showed. The second type is not known with certainty in nature; hybrids possessing a pair of characters of this kind would in the first generation exactly resemble the parent with the dominant character, and the second on later generations would be exactly like the first. In the case of the third type, hybrids with such characters would in the first generation show a character intermediate between those of the parents, the two characters would however be separated in the sexual cells, and the two kinds of gametes being produced in equal numbers there would arise, by self fertilisation, three classes of forms; (1) 25% pure forms with one character, (2) 25% pure forms with the other character, (3) 50% hybrid forms with the new intermediate character. The later generations would behave similarly and there would, as in Pea hybrids, be a rapid diminution in the proportion of hybrids in the offspring; as however there is no dominance of one character, the three classes of forms would always be clearly distinguishable. Examples of pairs of characters of this type are found in the hybrids between races of *Zea Mays*, so Correns terms this the *Zea*-type. In the fourth type the first generation of the hybrids would show a character intermediate between those of the parents and the later generations would be like the first; *Hieracium* hybrids exhibit a number of characters which conform to this rule so that Correns calls the type after this genus.

Correns investigated with great care the behaviour, on crossing, of a large number of differentiating pairs of characters in thirteen constant races of Maize and found examples of all the types described above, except the second. Of the Pisum-type the best example was the chemical nature of the endosperm *i.e.* whether starchy or sugary. When a race with a starchy endosperm was crossed with a race with a sugary endosperm, the resulting hybrids had always starchy endosperm whichever way the cross was made; in the second generation, after self-fertilisation, 25% of the forms had sugary endosperm, the rest starchy, so that this pair of characters is clearly heterodynamic and schizogonous. To this category also belong pairs of characters in relation to the nature and colour of the glumes and also those relating to the colour of the endosperm and aleurone layer in the second and following generations (but not in the first). To the *Zea*-type were found to conform pairs of characters in relation to the form of the cells of the aleurone-layer (whether long or short), the colour of the grain coat, and the colour of the endosperm and aleurone-layer in the first generation. Under the *Hieràcium* type are included pairs of characters in relation to the form and size of the grain, the weight relation of the embryo and endosperm, the size of the plant and fruit spike, etc.

These observations show clearly that in similar races, and even in one and the same race, characters of the three different categories may be found together. The matter is further complicated by the fact that schizogonous characters were sometimes found to be altered in value by the separation which takes place at gamete formation in the first generation (as is shown by the change of the characters for the colour of the endosperm and aleurone-layer from homodynamic to heterodynamic), and by the fact that the relative value of the two characters of a homodynamic pair is often affected (1) by the individuality of the gametes, (2) by the individuality of the plants, (3) by the nature of the race to which the plant belongs.*

Before considering further recent work, it will be convenient to give a brief account of the various types of behaviour which may be observed in a pair of characters of a hybrid during vegetative development (Correns, 1901, a, b). In the case of a homodynamic pair of characters the two characters may be equally strong in all cases, there will then be only one kind of hybrid which will be exactly intermediate in character between the two parent forms. Using A, a, as before, to represent the parental characters, and H as representing the hybrid, the condition may be then represented thus:—

......................H...................... (1)
A a

The two characters may, however, be unequally strong, but with the same one always the stronger and to the same degree, the hybrid will then approach in character one of the parents:—

... .H.................................... (2)
A a

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*Sex was found to have little real effect except in relation to the characters of the hybrid endosperms to be discussed later. The form and size of the grain were always those of the female parent in the first generation, because these two characters are dependent on non-hybrid characters, the form and size of the ovule and ovary. In later generations they were intermediate in form.

The extreme case of this tendency is obviously that of a heterodynamic pair of characters where the one completely masks the other:—

H.. (3)
A A

Again, of the two homodynamic characters, sometimes one, sometimes the other, may be more strongly developed, the hybrid then shows many forms and the pair of characters may be termed *poikilodynamic*:—

......H'......H''......H''......H'''......H''''...... (4)
A A

Lastly, an extreme case of the fourth class is possible, in which sometimes the one character, sometimes the other, is in abeyance and all intermediate forms are wanting; pairs of characters behaving in this way are aptly termed by Correns *dichodynamic*, thus:—

H..H (5)
A A

The last two cases are considered by Correns as special cases of homodynamic characters.[*]

Under the first two classes are included many of the characters of hybrids generally, and many of the characters of *Hieracium* hybrids and of *Zea Mays* races. The third class is well known and is observed in many of the characters of Pea hybrids. Under the fourth class must be included many of the characters of *Hieracium* hybrids also; as these characters are also homoiogonic there may arise from a single cross a number of new and constant (when self-fertilised) races of hybrids. The classical examples of the fifth (*dichodynamic*) class are the strawberry hybrids described by Millardet (1894); these are of two forms and exhibit either all the characters of the one parent or all those of the other, so that without a knowledge of their origin it would be impossible to tell that they were of hybrid nature. On account of this striking behaviour, Millardet was led to call these hybrids "faux hybrides."

The very interesting cases of "mosaic" formation in hybrids may be considered as special cases of either class 4 or 5, in which the varying value of the two characters is exhibited not in different individuals but in different parts of the same individual. An example of the first case is seen in the hybrid endosperm, produced by crossing white and blue Maize races, in which the flecks of colour show all gradations between blue and white, the mosaic being thus made up of *poikilodynamic* pairs of characters. An example of "mosaic" formation where the pairs of characters are *dichodynamic* is well seen in the hybrids between the blue and white flowered races of *Veronica longifolia* or the hybrids between races of *Mirabilis Jalapa* described by Naudin in 1863, where the flowers of the hybrid are striped with red and white, the colours respectively of the two parents. In "mosaic" formation, instead of the relative value of the two characters (or the supremacy of one) being constant throughout the whole individual, there may be a different value for a single branch, a single cell or even a single vacuole (as would appear from Correns' observation on the varying colour of the aleurone grains in the cells of the aleurone layer of the endosperm of Maize races).

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[*] It is obviously possible to consider the third case, that of heterodynamic characters, as only a special case of homodynamic characters in which one is always in abeyance, the difference between the two main classes would then be only one of degree. Correns (1901 B), in fact, considers that the two classes are not fundamentally different, as is suggested by the change from one class to the other mentioned above. The object of the classification is mainly for convenience of reference.

The earlier investigations of Correns (1900) on the behaviour of *Matthiola* hybrids must be mentioned, for in them apparently the separation of the schizogonous characters takes place according to a law other than that of Mendel. Eight pairs of differentiating characters were investigated in hybrids between *M. incana* and *M. glabra :* five of them were heterodynamic and the other three homodynamic, but with one character always much the stronger. The five dominant characters and the three stronger characters were all derived from M. incana. If these eight characters were schizogonous there should be produced, according to Mendel, 256 (2^8) kinds of sexual cells, and in the next generation two plants exactly like the parents should occur only once among 65536 individuals. Such a pair of forms was however met with only among 16 plants. From this observation and from the fact that was certain of the characters were found to be correlated, Correns led to the belief that only *two* sorts of sexual cells arise, but in equal numbers, one with all the characters of one parent, and one with all the characters of the other.

De Vries, the evidence for whose results, however, has in the main not yet been published, while confirming (1900, A, B) Mendel as to the presence of heterodynamic and schizogonous characters in many hybrids, as stated above, has found aberrant cases in *Oenothera* hybrids (1900, D). Various forms were crossed, and the result was that with some crosses only one kind of hybrid was produced, while from others several forms arose. Some of the forms remained constant in the second generation, while others showed a separation of characters; while, exceptionally, there were produced from one and the same cross, forms, of which were some schizogonous and some homoiogonious, in relation to the same pair of characters.

Tschermak (1900, 1901) from a large series of experiments, makes clear the existence of homiogonous characters in Peas and Beans, and also confirms to a great extent the work of Mendel, but finds a few exceptions among Peas, even to the dominance of such characters as yellowness of cotyledon and smoothness of seed coat.

It is clear from the observations of Correns, Tschermak and De Vries that recent work, while confirming and extending the application of the laws enunciated by Mendel, has tended to show that these laws are only special cases of more general ones yet to be discovered. The value of his observations is however not lessened, and his work remains a pattern for all future researches on hybridization.

To him (as pointed out earlier), we largely owe the important conception of unit characters, a conception which recent work has done much to confirm, for it is clear that a consideration of schizogonous pairs of characters, whether homodynamic or heterodynamic, in which the characters (or rather their "Anlagen")* are separated in the gametes, suggests that they retain their separate entities in the development of the individual, but react upon one another, and affect the development of the respective characters to a various extent (as in homodynamic pairs), sometimes to the point of the complete extinction of one (as in heterodynamic pairs). It may be further said that Mendel's work, and all the recent work on hybrids, seems to point to a theory of heredity of the type of Darwin's Pangenesis in the form lately put forward by De Vries.

Weldon (1902), after pointing out the numerous exceptions to the law of dominance and that of Mendel, both in hybrids generally and Pea races themselves, puts forward the view that the behaviour of the character of a hybrid is dependent on the ancestry of the parents, as would be suggested by the Galton law of blended inheritance. Standfuss, from observations on butterfly hybrids, and De Vries (1900 B) from observations on various plant hybrids, have also stated, that of a pair of characters, the one which is phylogenetically the older is usually either the stronger or dominant; this, however, is not universally true. It would seem that the whole question as to the relation of the characters of the hybrid to the ancestry of the parents can only be settled by further observations.

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* By "Anlagen" we understand the germ or apparatus (whatever tmay be) which brings about the development of that character.

In conclusion, a few remarks must be made concerning the interesting work of Correns on Xenia in Maize, and on the question of the probable time and mechanism of separation of the characters of schizogonous pairs.

Correns' observations on hybrid *Zea*-races were originally undertaken in 1897 with the object of studying the direct effect of pollen on the fruit, or Xenia as it has been called by Focke, for which the Maize races, with their endosperms of various colours and natures, were obviously well suited. It was very soon clear the influence of the pollen, apart from that on the embryo, was confined to the endosperm alone, but in that structure its effect was very striking. There seemed to Correns at the time only two probable theories to explain this influence; either that the endosperm arose from a sexual fusion, or else that there was some ferment-action by the hybrid embryo on the endosperm. As there was not the least histological evidence for the first theory, Correns inclined towards a belief in the second. The discovery, however, of double fertilization by Nawaschin and Guignard in 1899 gave the necessary proof that the endosperm also was of hybrid nature, and showed the correctness of the first hypothesis. Recently the latter observer has proved the existence of double fertilization in *Zea Mays* itself.

The direct influence of the pollen is most striking in the colour of the aleurone-layer and endosperm, and in the chemical nature of the reserve material. As was stated earlier, starch was found to be dominant over sugar whichever way the cross was made, but in the other two categories, the endosperm, though intermediate in character between the parents, much more strongly resembled the female parent. Further, in the case of the form of the cells of the aleurone-layer (whether long or short), foreign pollen had no effect at all in the first generation, though this pair of characters was obviously homodynamic, as later generations showed. It is thus clear that there is a striking general tendency for the hybrid endosperm in the first generation to resemble more strongly the female parent. The simple explanation put forward by Correns is no doubt the correct one, that, as the hybrid endosperm is derived from a triple nuclear fusion in which *two* nuclei come from the embryo sac and only *one* from the pollen tube, there must be a tendency towards the stronger development of the female character. It is also interesting to note that the endosperm characters investigated were all schizogonous in nature, and that the hybrid endosperm produced was of a similar hybrid nature to that of the embryo, a fact which shows, that the two polar cells (or nuclei) were of the same nature as the egg cell (or nucleus) and that the two male cells also possessed the "Anlagen" of the same characters.

The interesting hypothesis of Webber (1900) that in many cases the "flecking" of the endosperm is to be explained by the parthenogenetic development of the second male nucleus, is shown by Correns (1901 B) to be untenable. The endosperm often shows such characters that it must, on this theory, have developed partly under the influence of the three fused nuclei and partly under the influence of the male nucleus alone.

As was mentioned above, Correns soon found from his experiments that the direct effect of the foreign pollen was confined to the embryo and endosperm. This has led him to investigate the very puzzling cases of Xenia in which the pollen has been described as directly affecting structures other than the embryo and endosperm, *i.e.* tissues which are not of hybrid origin. He points out that some of the cases are to be explained by changes in the endosperm and embryo, and that for others there is no really trustworthy evidence. The subject cannot be discussed here, but his general conclusion is, that there is as little satisfactory evidence for this class of Xenia as there is for the existence of true graft-hybrids, or of telegony amongst animals.

The interesting speculative questions as to the means by which the schizogonous characters, really their "Anlagen," are separated in the sexual cells, and the time at which it occurs, have been discussed by Correns (1900 B, 1901 B) and Strasburger (1900, 1901), and brief reference must be made to them. Correns, from a consideration of the fact that in the simplest case with one pair of differentiating characters, the two kinds of gametes are produced in *equal* numbers, puts forward the view that the mechanism of separation is that of a nuclear division, physiologically of the nature of Weismann's reducing division, but not necessarily by means of an actual *cross*-division of the chromosomes. This view is fairly easily conceivable when there is only one pair of characters to be considered, but when the pairs of characters are numerous, and when some are schizogonous and some homoiogonous the explanation is not nearly so satisfactory. Correns further suggests that the division which brings about the separation of the characters in the egg cell is the one which gives origin to the mother cell of the embryo sac, for his observations have shown that the two polar nuclei and the egg nucleus are all of the same nature, so that all the eight nuclei of the embryo sac must be similar in relation to the "Anlagen" of the characters considered. In formation of the male cells, however, Correns' view is that the two "Anlagen" are not separated till the latest possible time, *i.e.*, the division which gives origin to the vegetative and generative cells of the pollen grain. This view is based on the fact that in crosses between the red flowered races (with greyish-green pollen) and white flowered races (with yellow pollen) of *Epilobium angustifolium*, all the pollen grains in the first generation were grey-green like the red flowered parent, and not half greyish-green and half white, as would be expected if the separation had taken place by means of the division which gives origin to the pollen mother-cells.

Strasburger's view is, that in the formation of both the male and female cells the separation takes place at the time of the reduction in number of the chromosomes, for at that time the nuclei undergo a profound alteration in form, and at that time only is there any histological evidence for such a separation. He also suggests that the evidence deduced from the pollen grains of *Epilobium* hybrids is not satisfactory, for it is probable that the walls of the pollen grains are laid down under the influence of the nuclei of the tapetal cells, and not under that of the nuclei of the pollen grains. The subject is one of considerable difficulty, and Corren himself admits that the question is not yet settled. He is attempting to obtain more evidence by further experimental work.

1901. Bateson, W., Introd. to transl. of Mendel's Versuche über Pflanzenhybriden. Jour. Roy. Horticult. Soc., Vol. 26, pt. 1.

1900, A. Correns, C., G. Mendel's Regel über das Verhalten der Nachkommenschaft der Rassenbastarde. Ber d. Deutsch. Bot. Ges. Bd. xviii.

1900, B ——— Gregor Mendel's "Versuche iber die Pflanzenhybriden" und die Bestätigung ihrer Ergebnisse durch die neuesten Untersuchungen. Botan. Ztg. Bd. 58, Sp. 229.

1900, C. ——— Ueber Levkoyenbastarde. Zur Kenntniss der Grenzen der Mendel'schen Regeln. Botan. Centralbl., Bd. 84, s. 97.

1901, A. ——— Ueber Bastarde zwischen Rassen von Zea Mays. Ber. d. Deutsch. Bot. Ges. Bd. xix., s. 211.

1901, B. ——— Bastarde zwischen Maiserassen mit besonderer Berücksichtigung der Xenien. Bibliotheca botanica, Heft 53.

1902. ——— Die Ergebnisse der neuesten Bastardforschungen für die Vererbungslebre. Ber. d. Deutsch Bot. Ges. Bd. xix. Gen-versammlgs-Heft. s. (71).

1866. Mendel, G., Versuche über Pflanzenhybriden. Verhandl. des naturf. Vereins in Brünn.

1870. ——— Ueber Hieracium-Bastarde, Ibid.

1894. Millardet, A., Note sur l'hybridation sans croisement ou fausse hybridation. Mem. Soc. Sc. phys. et natur. de Bordeaux. Tom iv., 4 série.

1900. Strasburger, E., Versuche mit diöcischen Pflanzen in Rücksicht auf Geschlechtsvertheilung. Biolog. Centralbl Bd. xx.

1901. ——— Ueber Befruchtung. Botan. Ztg. Bd. 59, Nr. 23, s. 354.

1900. Tschermak, E., Ueber künstliche Kreuzung bei Pisum sativum. Zeitschr für das landwirthschaftl. Versuchein Oesterreich. 5 Heft—Kurz Bericht: Ber d. Deutsch. Bot. Ges. Bd. xviii., Heft 6, s. 593.

1901. ——— Weitere Beiträge über Verschiedenwerthigkeit der Merkmale bei Kreuzung von Erbsen u. Bohnen. Ibid—Kurz Bericht. Ber. d. Deutsch Bot. Ges. Bd. xix., Heft. 2. s. 35.

1900A. Vries, Hugo de. sur la loi de disjonction des hybrides. Compt. rend. Acad. d. Paris, 26 Mars.

1900B ——— Das Spaltungsgesetz der Bastarde. Ber. d Deutsch. Bot. Ges. Bd. xviii., Heft. 3, s. 83.

1900. ——— Ueber erbungleiche Kreuzungen. Ibid, Bd. 18, s. 53.

1900. Webber, H. J. Xenia or the immediate Effect of Pollen in Maize. U.S. Dept. Agric. Bull. No. 22.

1902. Weldon, W. F. R. Mendel's Law of Alternative Inheritance in Peas. Biometrika, vol. 1, part 2.

THE ORIGIN OF THE SEED-LEAF IN MONOCOTYLEDONS.

By Ethel Sargant.

It is now five years since I began the study of the vascular system in Monocotyledonous seedlings. My object from the first was to throw light on the race-history of Angiosperms. A general probability is acknowledged that systematic characters drawn from the structure of the embryo possess, in plants as in animals, a special claim to attention. The study of vegetable embryology has, however, been hitherto singularly barren of such results, and has yielded but one character of systematic value. The presence or absence of endosperm in the ripe seed, though an important character, can hardly be considered as strictly embryonic.

The number of the seed-leaves in the embryo is the single character to which I have referred as of acknowledged systematic value. The fundamental division of the Angiosperms is that which separates plants possessing one seed-leaf from those possessing two. The other characters which distinguish Monocotyledons from Dicotyledons are merely corroborative, and are subject to many variations.

Recent research has tended to show that the Angiosperms are a very well-defined group, separated from all others by the possession of a true endosperm—that is, a food-body, formed after fertilization, within the embryo-sac, independently of the embryo, but side by side with it. The breadth of the gulf separating the Angiosperms from the Gymnosperms and higher Pteridophytes can hardly, in the present state of knowledge, be attributed entirely to our ignorance. There must be a real absence of intermediate groups, though we may hope to discover some stray forms, living or fossil, which may indicate how in past ages that gulf was bridged.

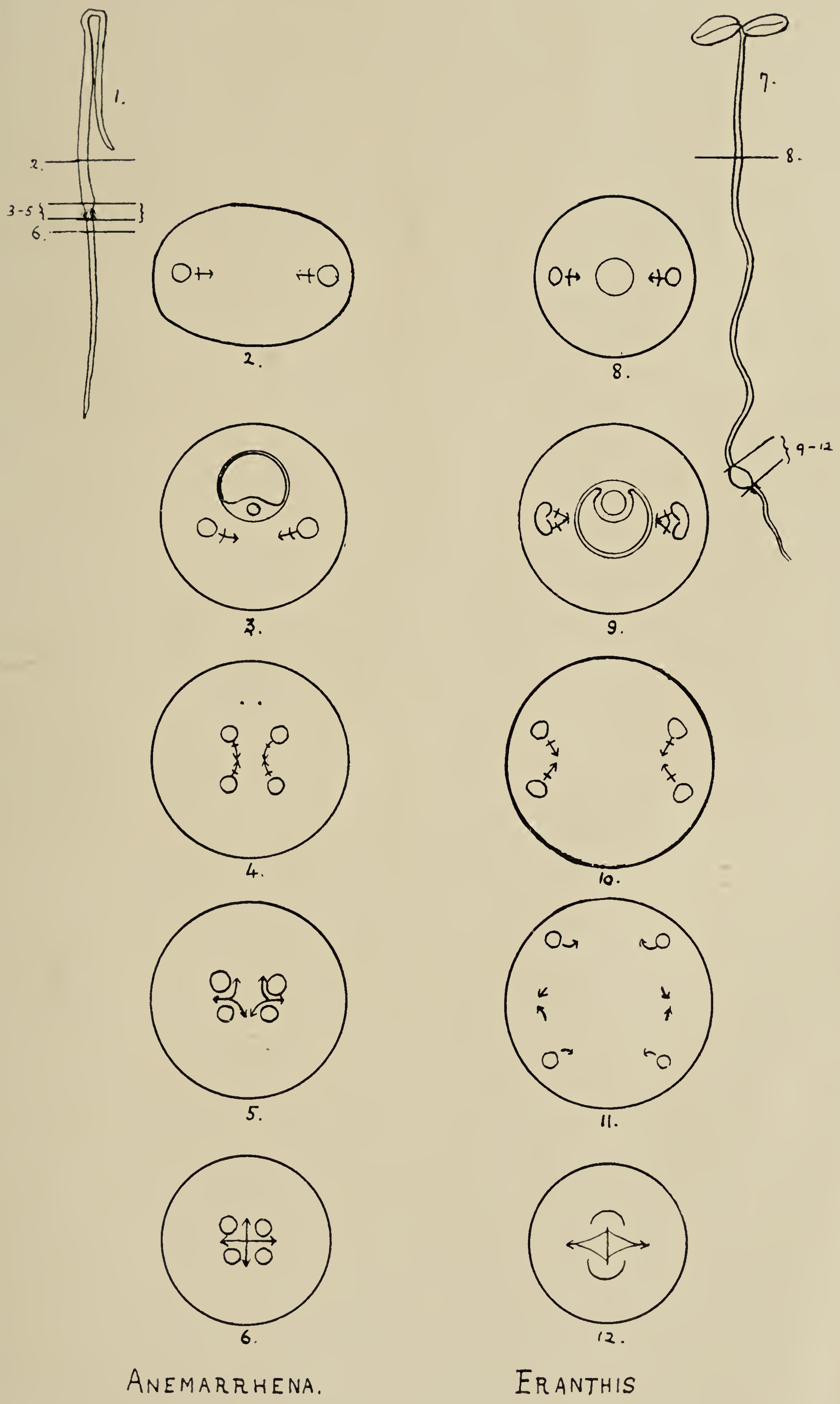
When we realize the isolation of the Angiosperms, the dividing-line between the two main groups into which they fall appears less marked than before. The common ancestor of Monocotyledons and Dicotyledons may have been quite unlike any existing species of either class. It may have combined features from both, and yet have been an undoubted Angiosperm. It almost certainly possessed either one or two seed leaves. If the former, the Monocotyledons must be considered the more ancient group; if the latter, the Dicotyledons.

The first question arising from the study of the vascular system in young seedlings is whether the course and symmetry of the bundles within the cotyledon and hypocotyl can be treated as characters possessing any phylogenetic value. To work out the seedling anatomy of some one family as completely as possible seemed the best way of attacking the problem, and my choice fell on the Liliaceæ. Abandoning the study already begun of Monocotyledonous seedlings in general, I collected and examined Liliaceous seedlings only. During the past four years I have collected and preserved seedlings belonging to sixty genera of this family. The detailed examination of these forms—in which I have been ably assisted by Miss Thomas—is not yet complete, The species I have thoroughly worked out belong for the most part to the four central tribes of the family: Asphodeleæ, Allieæ, Scilleæ and Tulipeæ; but I have also described a number of species from the Aloineæ, Dracaeneæ, and from some of the outlying tribes.

No doubt now remains, in my mind, as to the systematic value of the indications given by the vascular structure of the cotyledon, hypocotyl and primary root. Such indications, however, can only be interpreted by the light of a wide experience. The primitive structure of the cotyledon and primary root is constantly concealed —wholly or in part—by the presence of adaptive characters. These are commonly less conspicuous in the hypocotyl, but the structure of this also cannot fail to be affected by alterations in that of the cotyledon and root.

Seedlings are thrown on their own resources at so early a period in their life history, that the struggle for existence, repeated through many generations, often transforms their whole structure. At the time of germination this structure is still so little differentiated as to be extraordinarily plastic.

For some time, though recognizing certain embryonic characters as common to groups of genera, I found no vascular arrangement which there was any ground for considering primitive: none, that is, from which the ground-plan of several other groups could be readily derived. The first seedlings examined were those of bulbous species: *Lilium*, *Fritillaria*, *Allium*, and others. In all these genera the cotyledon early appears lateral with respect to the succeeding leaves. I learnt to look on an asymmetrical bundle-arrangement as characteristic of monocotyledonous hypocotyls, and became familiar with the various schemes according to which the lateral cotyledonary trace or traces passed into a central and symmetrical root-stele.



E.S. del.

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These schemes are of two kinds: in *Lilium* and other genera of the Tulipeæ, for example, the cotyledonary traces themselves change from an asymmetrical to a symmetrical orientation as they pass downwards through the hypocotyl. The Allieæ, on the contrary, depend on plumular traces to complete the symmetry of the root-stele.

Had this asymmetrical ground-plan turned out to be essentially monocotyledonous, as I then thought it, two views of its origin were possible. Such a cotyledon as that of *Lilium* might be considered as originally terminal, but early pushed aside by the more vigorous plumule. This would suggest the superior antiquity of Monocotyledons, and the derivation of Dicotyledons from an ancestor with one seed-leaf. The structure of *Allium*, on the other hand, admitted of a different explanation. Its cotyledon might conceivably be lateral in origin as well as in appearance. The second half of the root-stele might originally have been supplied by the traces of a second cotyledon opposite the first It was easy to conceive of a series of forms in which the traces of the plumule should step by step replace those of a gradually disappearing seed-leaf.

When at length a form was reached from which others were clearly derived, I found to my surprise that it was truly symmetrical throughout. The ground-plan of *Anemarrhena* is unmistakeable in the allied genera *Asphodelus* and *Asphodeline*. Through the intermediate forms of *Chlorogalum* and *Anthericum*, it is connected with *Arthropodium*, and the ground-plan of *Arthropodium* is very similar to that of *Allium* and its allies.

The vascular systems of seedling Asphodeleæ and Allieæ are thus linked together by the probably ancient structure of *Anemarrhena*. The vascular system of its cotyledon, hypocotyl, and primary root—already described elsewhere in detail[1]—is given in the series of diagrams 2-6. It is, as I have said, a symmetrical system. The cotyledon is a somewhat flattened green cylinder ending in a tapering green apex, which in young seedlings is still enclosed within the seed-coat. The plumule is developed rather late. In the seedling figured it is still quite embryonic, and is completely enclosed within the base of the cotyledon. The axis is slightly thickened just below the plumule, and it passes at once into the very well-developed primary root (fig. 1).

Two massive bundles run the whole length of the cotyledon. In transverse section it is somewhat elliptical, and the bundles are placed near the two foci (fig. 2). Lower down they are displaced a little from this symmetrical position by the formation and growth of the plumule (fig. 3). This displacement, too slight to be considered significant, makes itself felt into the transitional region (figs. 4, 5). The transition takes place, however, in a perfectly symmetrical way. Each xylem group gives off three branches of protoxylem, and each group of phloëm divides into two (fig. 5). The four lateral branches of protoxylem fuse in pairs, and the result is a tetrarch root-stele (fig. 6).

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[1] E. Sargant, Ann. of Bot., vol. xiv., 1900, p. 633.

Later observations have strengthened my conviction that the vascular characters observed in the seedling *Anemarrhena* are primitive. The same structure—with one trifling exception, to be considered later—is found in *Albuca*, among the Scilleæ, and a very similar vascular system occurs in seedlings of the neighbouring genus *Galtonia*. All the other forms which I have examined from the Scilleæ can be derived from these. For example, the very distinct structure characteristic of *Hyacinthus* and some other genera is connected with the *Albuca* type by a number of intermediate forms found within the single genus *Muscari*. Further, within the genus *Scilla* we have the *Hyacinthus* type leading on to a form closely resembling that of *Lilium* and other Tulipeæ. Thus it appears that the *Anemarrhena* type is the starting point of at least four central tribes within the Liliaceæ, and it must therefore be a form of some antiquity among Monocotyledons.

So early as August, 1900, I find a paragraph in my notes suggesting that the two bundles of the cotyledon and hypocotyl of *Anemarrhena* may be traces representing the two distinct cotyledons of some ancestor. If this view is justified, the "cotyledon" of *Anemarrhena*, and probably that of all Monocotyledons, must be equivalent to both the seed-leaves of a Dicotyledon.

This hypothesis gained in importance and probability as the primitive character of the *Anemarrhena* type became apparent. Soon after cutting *Albuca* and *Galtonia*, I resolved to examine some Dicotyledonous seedlings for comparison. The point of attack was decided by the well-known monocotyledonous affinities of the Nymphaeaceæ and Ranunculaceæ, and while collecting material from both families I was so fortunate as to meet with the detailed work on Ranunculaceous seedlings published by M. Sterckx[1]. The resemblance in vascular symmetry between such forms as *Eranthis* on the one hand and *Anemarrhena* and *Albuca* on the other, was clear at once from the figures in this paper and the accompanying descriptions. My own examination of *Eranthis* draws the parallel even closer. The two series of diagrams placed side by side on Plate (figs. 2-6 and 8-12) show an astonishing likeness in the arrangement and course of the bundles which traverse the transitional regions in the two species figured.

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[1] R. Sterckx, Mém. de la Soc. Royale des Sciences de Liège. 3ième sér., tom. ii., 1899.

The cotyledons in an *Eranthis* seedling of the age shown in fig. 7 are united for the greater part of their length. Their blades are distinct, but the long petioles form a slender cylinder, solid just beneath the blades and again in the region above the stem-bud, but hollow between those levels (fig. 8), and opening out again into a conical chamber over the tuber. Within this hollow is the very small stem-bud, seated on the tuber, and completely enclosed within the cotyledonary tube (fig. 9).

Three bundles from each cotyledon enter the petiolar cylinder, but very near the top of it the two lateral traces from each blade unite with their own midrib. From this level downwards the petiolar cylinder contains two massive bundles, each representing a separate cotyledon (cf. Sterckx, loc. cit., Pl. xix., figs. 250, 251 and others).

The section which passes through the stem-bud shows each cotyledonary bundle opening out into two in a characteristic way (fig. 9). The two halves separate like two flaps of a screen, the protoxylem group representing the hinge. The insertion of the little-developed plumular traces on those of the cotyledon does not affect the symmetry of the transition. As we descend in the tuber every trace of this insertion disappears. Each cotyledonary trace opens out until the stage shown in fig. 10 is reached. There are now four distinct bundles of the stem-type in the hypocotyl, arranged in pairs at either extremity of one diameter.

Following the series of sections downwards, all the traces become more widely separated as the tuber increases its girth, for they keep near the periphery. As each pair of bundles separates three xylem groups are formed: one within each of the two phloëm groups, and a third half-way between them. This median xylem group finally divides, and then we have the structure shown in fig. 11. Four phloëm and eight xylem groups are arranged at fairly regular intervals round the periphery of the tuber, which has now almost reached its maximum diameter. As it narrows again towards the base, the xylem collects into four masses. The arrowheads in fig. 11 point out how this takes place. The four phloëm masses at the same time fuse in pairs, and each double group places itself outside one of the four xylem masses (fig. 12). The stele narrows very quickly here, for the bundles leave the periphery and approach the centre. A diarch root-stele is formed: two opposite groups of protoxylem disappearing (fig. 12).

The resemblance between figs. 2-5 and 8-11 needs no comment. The structure of *Eranthis* is rather more symmetrical than that of *Anemarrhena*, owing to the one-sided position of the stem bud in the latter (fig. 3.) The cotyledonary traces of *Eranthis* also reveal their double character more clearly than those of *Anemarrhena*. Comparing fig. 8 with figs. 9-11, no one would hesitate to consider the two bundles of fig. 8 as representing in fact four, united in pairs throughout the length of the cotyledons, but betraying their real character at the base of the cotyledonary tube (fig. 9.). They behave as four throughout the transition (fig. 11), following Van Tieghem's first type except that the resulting root is diarch not tetrarch. (Traité de Botanique, Vol I, p. 782).

In *Anemarrhena* the corresponding traces never separate so completely into four, at least in the upper part of their course, but they are all represented in the root-stele which becomes and remains tetrarch.

In the formation of a diarch root from a system of traces which suggests a tetrarch symmetry, the seedling of *Eranthis* follows that of the allied genus *Nigella*. The vascular structure of the seedling *Nigella damascena* has been described at length by MM. Gérard,[1] Dangeard,[2] and Sterckx (loc. cit. pp. 5-24 and Pl. i.-viii. in the separate copy.)

It is at first difficult to understand why the cotyledonary traces of *Anemarrhena*, which are more reduced in the upper part of their course than those of *Eranthis*, should retain their independence more completely in the root. The explanation perhaps lies in the power possessed by Dicotyledons of increasing their root-girth by secondary thickening. A Monocotyledon has no such resource. If its primary root is to become a stout and long-lived member, the root-stele must be designed on a generous scale.

The seedling of *Fritillaria imperialis* offers a good example of adaptation to this necessity. The primary roots of *F. alpina* and other species of the genus are slender and comparatively short-lived. They possess a diarch stele which is formed from two cotyledonary traces in the manner characteristic of the Tulipeæ.

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[1] R. Gérard, Ann. des Sci. Nat. 6ième sér. tom. xi. p. 279, 1881.

[2] P. Dangeard, Le Botaniste. 1ière sér. p. 75, 1889.

F. imperialis has two cotyledonary traces also, and the transition follows the usual course until a very massive diarch root-stele has been formed. But the primary root in this species is stout and unusually long-lived. The diarch stele breaks up immediately after its formation into a polyarch stele with six or seven phloëm and xylem groups.

It is interesting to note in this connexion that the seedlings of *Albuca Nelsoni* show a tendency to root-reduction. In one of the three seedlings I examined, the transition takes place precisely as in *Anemarrhena.* The two cotyledonary traces form a tetrach root-stele after the same fashion. But in the other two specimens the root becomes triarch by union of two phloëm groups and suppression of the intermediate xylem ray. The root-reduction now sterotyped in *Nigella* and *Eranthis* may have begun in a similar way.

In conclusion, the hypothesis that the vascular system in the seedling of *Anemarrhena* represents the bicotyledonary system of a remote ancestor, gains very much in probability when we find that a similar vascular reduction has taken place in such a form as *Eranthis hiemalis*, where the partial union of two cotyledons is undisputed. Moreover, if the hypothesis be admitted, the disputed case of *Ranunculus Ficaria* becomes clear No adequate discussion of its structure can be given here, but after careful examination I agree with M. Sterckx in considering the cotyledonary member found in this species as undoubtedly formed by the union of two cotyledons.

To conceive of steps by which two separate cotyledons should gradually unite is easier than to imagine a single cotyledon splitting into two similar members, as suggested by Mr. H. L. Lyon.[1]

Nor is there any evidence of weight for the superior antiquity of Monocotyledons. I have regarded them for some time as specialized forms of an ancestor with two seed-leaves. The complete union of the cotyledons may very possibly be due to their common specialization as a sucking organ. It is true that all cotyledons begin life by absorbing nourishment from a food-body within the seed, but in dicotyledonous seedlings they commonly lay aside that function at an early period, even though they may never become assimilating organs. Among Monocotyledons on the cont ary the apex of the cotyledon often remains within the endosperm throughout the existence of both, a period which covers years in Palms and some other plants. Such a habit as this would naturally lead in course of time to the fusion of the cotyledons within the seed.

Quarry Hill, Reigate, *April 26th, 1902.*

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[1] H. L. Lyon, Minnesota Botanical Studies, 1901. pp. 643-655.

A REVISION OF THE CLASSIFICATION OF THE GREEN ALGÆ

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(*continued from page* 96.)

Fam. VI. Hydrodictyaceae.

Plant-body an immotile cœnobium of cœnocytes, formed by the apposition and union of free zoospores which, however, have not escaped from the mother cœnocyte. Reproduction also by isogametes. Germination indirect, the zygote increasing in size and producing swarmers which come to rest and form "polyhedra" in which zoospores are produced, and by apposition and union give rise to new cœnobia.

1. *Euastropsis.* Lagerheim, 1894.

Cœnobium of two cœnocytes (?). Zoospores 2-32, joining in pairs to form one or more cœnobia in each mother-cœnocyte. Gametes unknown.

2. *Pediastrum.* Meyen, 1829.

Cœnobium of 2·64 cœnocytes, forming a plate, continuous or with gaps. Marginal cœnocytes generally lobed, and with the wall extended into horns. Chromatophore parietal with one pyrenoid.

3. *Hydrodictyon.* Roth, 1800.

Cœnobium of very numerous large cylindrical cœnocytes, each of which may attain 1 cm. in length, joined end to end to form a net extended in three dimensions. Protoplasm in each cœnocyte lining the wall and enclosing a large central vacuole. No separate chromatophore; the whole of the cytoplasm, except the ectoplasm and vacuole wall, containing chlorophyll, and with pyrenoids and nuclei distributed through it.

Series 2. **Siphonales.**

Thallus a cœnocyte or an aggregate of cœnocytes, usually taking the form of a branched filamentous system, fixed below to a substratum, the branches free or secondarily attached to one another or interwoven to form a more or less massive thallus. Protoplasm in a parietal layer, surrounding a central vacuole and containing numerous nuclei; chromatophores usually numerous, oval or angular discs, with or without pyrenoids.

Reproduction by means of biflagellate (rarely quadriflagellate) zoospores, or by the conjugation of isoplanogametes, or rarely heterogamous; sometimes by fragmentation of the thallus or by aplanospores.

(*a*) SIPHONEÆ. Thallus of a single cœnocyte, rarely secondarily septate except in connection with the formation of reproductive organs. All the forms except *Protosiption* are marine.

Fam. I. PROTOSIPHONACEÆ. Thallus consisting of *a simple tubular or bladder-shaped shoot attached below by a simple* or slightly branched colourless *root.*

[It is probable that the two genera we have included in this family have no close affinity, but they are conveniently classed together as two of the simplest expressions of the Siphoneous tendency.]

Genera.

1. *Protosiphon.* Klebs, 1896.
   Shoot spherical to tubular, with a reticulate parietal chromatophore containing several pyrenoids. Root a direct continuation of the shoot and absorbing water from the soil in accordance with the terrestrial habit. Reproduction by division of the entire young cœnocyte, or by the budding off of new individuals from the shoot, or by division of the contents of the shoot into (1) facultative isogametes, or (2) aplanospores which may either germinate directly or themselves become gametangia. The alternative methods of reproduction are directly determined by external conditions.
2. *Codiolum.* A. Braun, 1852.
   Shoot club-shaped. Root without a cavity, in accordance with its aquatic (marine) habitat. Reproduction by aplanospores or biflagellate swarmers.

Fam. II. BRYOPSIDACEÆ.

Thallus a branched cœnocytic tube. Basal branches developed as fixing organs (roots). *Shoot* consisting *of a main ascending axis* ("*stem*") *which bears branches of both limited and unlimited growth* ("*leaves*" *and axes of the second order*). Chloroplasts numerous, small, flat, ellipsoidal. each with one pyrenoid.

Reproduction by the conjugation of planogametes produced in leaves which are shut off from the stem by secondary septa.

Genus.

Bryopsis. Lamouroux, 1809.
Branches and leaves arranged distichously on the axis. Anisogametes. Plants diœcious.

Fam. III. DERBESIACEÆ.

Thallus a simple or slightly branched tubular cœnocyte. *No differentiation into stem and leaves.* Chloroplasts oval, discoid, with or without pyrenoids.

Reproduction by zoospores, produced in spherical or club-shaped lateral branches of limited growth. *Zoospores rounded, with a crown of cilia* at the colourless anterior end.

Genus.

Derbesia. Solier, 1847.

Characters of the family.

[Though the vegetative characters of this genus suggest a position among the lower Siphoneæ in the neighbourhood of *Bryopsis*, yet the peculiar zoospores, recalling those of *Œdogonium*, probably indicate that its affinities are widely different. Our present information is not however sufficient to justify the removal of the genus from its traditional place.]

Fam. IV. CAULERPACEÆ.

Thallus a branched cœnocyte; axis a creeping, branching "rhizome" bearing fixing, slightly branched "roots" below, and "fronds" above. The latter are *very variously differentiated, often closely imitating the external forms of different higher plants.* Vacuolar cavity traversed by "beams" of cellulose, whose function is probably to tie the external walls together.

Reproduction by fragmentation of the thallus; the wounds so produced being very readily healed. No reproductive cells known.

Genus.

Caulerpa. Lamouroux, 1809.

Characters of family. The genus is divided into twelve sections according to external characters.

Fam. V. CODIACEÆ.

Thallus a much branched cœnocytic tube. *Branches thread-like, loosely or closely interwoven to form a thallus of definite external form,* which may shew an external differentiation of parts, and an internal differentiation into a central region with longitudinally running threads (pith), and a peripheral region with outwardly directed branches (cortex). Thallus fixed below by root-threads. Surface of thallus often wholly or partially incrusted with calcium carbonate. Chromatophores numerous, round or elliptical, with or without pyrenoids.

Reproduction insufficiently known; sometimes by the formation of biflagellate swarmers in special branches (zoosporangia or gametangia) shut off from the main tube; usually by fragmentation (?)

Genera.

1. *Avrainvillea.* Decaisne, 1842.

Thallus either undifferentiated, of loosely interwoven, dichotomously branched threads, or differentiated into a stipe and frond, with the constituent threads closely interwoven to form a compact tissue-like body. No differentiation into pith and cortex.

2. *Penicillus.* Lamarck, 1813.

Thallus consisting of a cylindrical or slightly flattened stipe formed of closely interwoven threads and encrusted with calcium carbonate, terminated by a crown of free, diverging, dichotomously branched threads. Root of numerous dichotomously branched threads. Stipe with well-marked differentiation into pith and cortex.

3. *Rhipocephalus.* Kützing.
   Thallus consisting of a cylindrical encrusted stipe, bearing above several flat fronds consisting of closely interwoven threads.

4. *Callipsygma.* J. Agardh, 1887.
   Characters of *Rhipocephalus*, but stipe flattened. The edges bear ridges, from the summit of each of which a flat frond arises; all the fronds lie in the same plane.

5. *Udotea.* Lamouroux, 1816.
   Thallus of a cylindrical or flattened, creeping or erect stipe, simple or branched, and bearing one or more simple flat fronds, which shew concentric zones of growth. Stipe with differentiation of pith and cortex; frond with or without such differentiation. Incrustation present or absent. Zoosporangia (?) round, on short side-branches of the frond-threads.

6. *Halimeda.* Lamouroux, 1812.
   Thallus usually strongly incrusted, composed of branched series of wedge-shaped or reniform flattened segments, often all lying in one plane. Marked differentiation of pith and cortex. Cortical branches hexagonal by mutual presure. Zoosporangia (?) round or club-shaped, aggregated in botryoidal clusters on the edges of the thallus-segments. Swarmers observed.

7. *Pseudocodium.* Weber van Bosse, 1895.
   Habit of *Codium*, but the cortical branches adhering very closely together, and hexagonal by mutual pressure as in *Halimeda*.

8. *Codium.* Stackhouse, 1795-1801.
   Thallus of various shapes, crustaceous, spherical, or cylindrical and branched. No external differentiation of parts, but a well marked central pith, consisting of longitudinally running, parallel threads, from which arise club-shaped branches arranged perpendicularly to the surface, forming the cortex. No incrustation. Gametangia obovoid branches of the cortical threads, containing anisoplanogametes of which the male are small and yellow, the female large and green. Plants diœcious.

Fam. VI. VERTICILLATÆ.

Thallus consisting of *a long, cylindrical, typically unbranched, undivided, upright stem*, fixed below by branched unseptate rhizoids, and *bearing* above *acropetal whorls of typically branched segmented appendages (leaves)*, delimited from the stem by closed or perforated septa, which are also found between the leaf-segments. Chloroplasts small, disc-shaped, with pyrenoids.

Reproduction by the formation in certain specialised fertile portions of the leaves, or in a special category of fertile leaves only, of isoplanogametes directly, or of aplanospores which may become gametangia or themselves germinate. Zoospores unknown.

Sub-Family 1. Dasycladeæ.

Leaves branched dichotomously or polytomously, all with a specialised terminal or lateral, fertile portion. Incrustation absent.

Genera.

1. *Dasycladus.* Agardh, 1827.
   Stem bearing closely set whorls of about twelve leaves each. Leaves several times polytomously branched, each branch forming a closed segment. Fertile portion of the leaf a stalked spherical gametangium, terminal on the basal leaf segment, and producing isoplanogametes. Germination of zygote not observed.
2. *Chlorocladus.* Sonder, 1871.
   Characters of *Dasycladus*, but the terminal branches of the upper leaves reduced to delicate hairs, and the contents of the fertile portion of the leaf dividing to form numerous aplanospores whose further development is unknown.
3. *Botryophora.* J. G. Agardh, 1887.
   Habit looser than in *Dasycladus*, with stiffer dichotomous or trichotomous leaves, and lateral spherical fertile portions, two to four together at the bases of the leaf-branches, producing numerous aplanospores.

Sub-Family 2. Cymopolieæ.

Characters of Dasycladeæ, but leaf-segments of either the first or second order swollen so as to come into lateral contact and form a continuous cortex, which is incrusted with calcium carbonate.

Genera.

4. *Neomeris.* Lamouroux, 1816.
   Stem bearing closely set whorls of branched, mainly dichotomous leaves. Cortex formed by swelling of basal portions of branches of the second order. Branches of higher order hair-like, deciduous. Fertile portions of leaves spherical, terminal on basal segments, each producing a single aplanospore.
5. *Bornetella.* Munier-Chalmas, 1877.
   Characters of *Neomeris*, but leaves polytomous, with fertile portions lateral, club-shaped, producing numerous spherical aplanospores.
6. *Cymopolia.* Lamouroux, 1816.
   Thallus consisting of calcified segments separated by uncalcified constrictions. Stem repeatedly dichotomous in one plane, bearing closely-set whorls of polytomously-branched leaves, the terminal branches hair-like and deciduous. The persistent bases of the leaves consist at the constrictions of the thallus of the basal leaf-segments only, but on the calcified thallus-segments also of the swollen branches of the second order forming the strongly calcified cortex. Fertile portions of the leaves as in *Neomeris*.

Sub-Family 3. Acetabularieæ.

Fertile and sterile leaves distinct, the sterile polytomously branched, fertile simple. Incrusted forms.

[According to Solms-Laubach the apparent simple fertile leaves are in reality lateral branches of compound leaves of which the other branches are reduced or absent.]

Genera.

7. *Halicoryne.* Harvey, 1859.
   Stem bearing alternating whorls of sterile and fertile leaves, the former polytomously branched, the latter simple, lanceolate, slightly inflexed, and producing a few strongly calcified aplanospores.
8. *Chalmasia.* Solms-Laubach, 1895.
   Fertile leaves in a single whorl, calcified, partially connate to form a terminal disc. Aplanospores (gametangia?) few, calcified.
9, *Acicularia.* D'Archiac, 1843.
   Fertile leaves wedge-shaped, in a single whorl laterally connate to form a terminal disc. Aplanospores (gametangia?) with lids, embedded in a calcareous homogeneous mucilage.
10. *Acetabularia.* Lamouroux, 1816.
   Stem bearing successive whorls of polytomously branched, deciduous, sterile leaves, and eventually a terminal whorl of simple fertile leaves laterally connate to form a disc. Each of these produce a number of oval gametangia, not incrusted, opening by a lid and setting free a number of isoplanogametes. Germination of zygotes direct.

(*b*) SIPHONOCLADEAE.

Thallus septate in the vegetative condition into segments containing at least two, usually many, nuclei.

[This group consists of a progressive series of forms in which the strictly siphoneous type is gradually abandoned, and the thallus becomes partitioned into smaller and smaller compartments which contain fewer and fewer nuclei. On germination of the zoospore in the most primitive forms quite a large strictly siphoneous thallus may at first arise, in which a number of secondary septa simultaneously afterwards appear. In the higher forms the septation takes place much earlier, so that the ontogeny does not so clearly recall the phylogeny. In those forms that depart most from the siphoneous type (unbranched Cladophoraceae) the septation is very abundant and the number of nuclei present in each segment is much reduced (sometimes to two), so that the thallus-segment approaches closely to the organisation of a true cell.]

Fam. VII. VALONIACEAE.

Thallus *when young truly siphoneous* for a longer or shorter time, but always (except in *Halicystis* and *Apjchnia*) *becoming partitioned when adult into segments containing a large number of nuclei* regularly spaced in the parietal protoplasm. The chloroplasts are very numerous angular discs typically arranged in chains to form an open net-work lining the wall. Plant attached by a branched rhizoid system (except *Halicystis.*)

Reproduction by typical zoospores observed in several cases. Gametes not known. All the forms are strictly marine.

Genera.

*Thallus strictly siphoneous.

1. *Halicystis.* Areschong, 1850.
   Thallus entirely unseptate, globoid, and attached by a delicate stalk and disc. No rhizoid system. Chloroplasts blunter-angled than in Valonia. Described as containing no starch.

[Schmitz has suggested the removal of this genus into the true Siphoneae, and *Apjchnia* should perhaps go with it. The absence of starch and rhizoids make its position doubtful until the development is fully known.]

2. *Apjchnia.* Harvey, 1855.
   Thallus erect, cylindrical, repeatedly polytomously branched, with constrictions at the points of origin of the branches. attached by a branched rhizoid system. The whole thallus is devoid of internal septa.

**Thallus a secondarily septate branch-system, without septa at the points of origin of the lateral branches.

3. *Siphonocladus.* Schmitz, 1878.
   Thallus either erect, columnar and slightly branched, or of confervoid habit, filamentous, and abundantly branched. The septa do not appear until the thallus has developed to a considerable size. Zoospores observed.
4. *Chamaedoris.* Montagne, 1842.
   Thallus consisting of a stout unseptate cylindrical stalk bearing above a large cup-like head composed of numerous filamentous irregular branches tightly interwoven.

***Thallus a secondarily septate branch system, septa always occurring at the points of attachment of the lateral branches.

5. *Valonia.* Ginnani, 1757.
   Thallus typically branched. The septa appear late in development and cut off lenticular, multinucleate, peripheral portions of the protoplasm, which may grow out into shoot or rhizoid branches of the thallus. Some species are globular and unbranched and possess only the single septum which always cuts off the unilocular rhizoid system from the shoot. Zoospores and aplanospores (?) observed.

(*To be continued.*)

R. Madley, Printer, Whitfield Street, W.

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TOWARDS AN IDEAL BOTANICAL CURRICULUM.

PART I.

THE following rough notions have been put together in the hope of contributing something towards an end that all teachers of botany should have at heart—a clearer understanding of the best things to teach and of the best ways of teaching them.

In a rapidly advancing science like our own, where the body of subject-matter is constantly, though gradually, shifting its outlines, where newer branches of knowledge are rapidly developing and tending to throw older ones into the shade, the question of what to teach and how to teach it is continually assuming new aspects. Occasional discussion between teachers on such points cannot fail to be of advantage all round.

An apology must be offered at the outset—the writer has no knowledge whatever of technical pedagogy; he is in the position of never having been taught how to teach, so that it is a case of struggling along by the light of nature, often, it is to be feared, a very feeble lantern indeed. Still the special problems that arise in having to deal with a special branch of science have to be faced by all whose business it is to teach it, and these lie largely outside the general principles of educational science.

A botanical curriculum may be divided into two parts, which roughly correspond to school and college or university; take the age of seventeen or eighteen as a dividing line between them. Of the teaching of botany to boys and girls under this age (to which this first article will be devoted) the present writer frankly confesses he has no experience whatever; he hopes that his ideas may be criticised and corrected by those who have.

It may be laid down as an axiom that the main object to be aimed at in teaching botany to a child is to get him to learn to look at and handle plants intelligently, and to become accustomed to their forms and habits. It is a commonplace that the advantage of real scientific education lies rather in training the power of observation and inference than in the acquirement of facts; and it is certainly the lack of this power in elementary students which so often handicaps the demonstrator in his attempts to instil a decent first-hand knowledge of the facts pertaining to the plants dealt with in an ordinary university course. With some happy exceptions the elementary student simply does not know how to begin to look at a plant, let alone a microscopic section, and a considerable amount of time is spent before the rudiments of this knowledge are acquired.

What then are the most suitable things to which to direct the attention of a child? Clearly the simplest and most fundamental. Reduced to its simplest terms, the germination of seeds is one of the easiest of experiments and is immensely instructive, especially if it can be started with the ripe seeds in the fruit. The transition from the apparently dead seed to the young growing plant is striking enough, and the causes and incidents of the change can be dwelt upon to any desired extent. For quite a young child, it will be quite enough to make him see for himself that a seed does not germinate unless it is damp and warm, to distinguish the root, cotyledons and shoot in different seedlings, and to notice that after a time the seedling will not go on growing without a supply of food.

At school, with older boys or girls, the main conditions of germination, the distinction between the storing of food in endosperm and in cotyledons, the distinction between seeds with epigeal and those with hypogeal cotyledons, and the various kinds of food required by the seedling after it has exhausted the reserve-stores, as shewn by water cultures, would make a full and most instructive term's course; and every bit of the observation and experiment can be done by the children themselves.

With regard to the physiology of the adult plant young children cannot be taught much in a systematic way. But where a garden is accessible or country walks can be taken, they can be taught to look intelligently at quite a number of points which will help to build up gradually some idea of the conditions of plant life. Such for instance are the relative luxuriance of the same species on different soils, the effects of shading, the fixed light-positions of leaves and branches, and so on. Many simple physiological observations and experiments suitable for schools may be found in Professor Farmer's useful little book on Practical Botany.

All details of descriptive botany, comparatively dry and unenlightening to the beginner, should be rigidly avoided, not only with young children but also in schools. Drudgery of this description tends only to disgust the child with the whole subject. The story told by Dr. Kimmins at the discussion on the Teaching of Botany, at last year's British Association, one may hope related to an exceptional case, but the method it illustrates is wholly vicious. Mites of seven or eight were found by an inspector writing down the whorls of a flower as gamopetalous, polyandrous, etc. "But do you suppose they understand in the least what these words mean," asked the inspector, "do they know any Greek?" "Well, no," said the mistress, "but then, you see how useful it would be if they should ever want to learn it!" There is the less excuse for this sort of thing nowadays, on the ground of the tyranny of the examination, as the recent Cambridge Junior Local papers have been set on remarkably broad and rational lines, the questions being such as would test a real first hand elementary knowledge of the factors which govern the life of a plant.

Children can be taught to look at flowers and understand a lot about them, and yet be burdened with scarcely any names. The biological side of the flower can always be kept in the foreground. The functions of the different whorls are all directly demonstrable by observations which could hardly fail to interest an intelligent boy or girl. The visits of insects can be watched in the garden or in the open country and with a very little patience many of the facts on which the biological "theory of flowers" is based can be made out at first-hand. The gradual swelling of the carpels after fertilization, and the ripening of the different kinds of fruits is just as interesting and as easily followed.

To turn to quite another branch of the subject, the facts connected with the universal distribution of bacteria and fungal spores, with the growth of these on various nutrient substances, and with their exclusion by sterilisation, might form the subject of a series of easily-conducted experiments, which, for some minds among the pupils of a school, have quite a peculiar fascination.

Only a few of the principal subjects that lend themselves to the sort of teaching indicated—a teaching in which the children should be made to do and see everything for themselves, the teacher giving but a few hints here and there—have been touched upon.[1] And yet

[1] We hope shortly to be able to publish an article by a high-school mistress who has had considerable experience and great success in this kind of teaching, describing her actual methods and their results.

how delighted would a university teacher be if his elementary students came up to him with the sort of knowledge and the sort of desire for fresh knowledge which such a training would have produced in an ordinary intelligent boy or girl of eighteen or so. The student entering a college or university need not know the name of a single natural order, he need not have even looked through a compound microscope, nor have heard of such a word as "obdiplostemony," but if he has a good first-hand acquaintance with actual plants and some idea of the way they live, the foundations of his botanical training have been well and truly laid. The ideal elementary university course, a most important and difficult subject, and the aims and methods of advanced university teaching, will be dealt with in our next number.

(to be continued).

HOW TO KEEP A SALT-WATER AQUARIUM FOR ALGOLOGICAL EXPERIMENTS.

A SALT-WATER Aquarium is often very valuable to the student of algology, as more minute and continuous observations can be made on seaweeds in this way than is possible by only examining them direct from the sea. I propose to give a short description of the best way of managing such an aquarium, based on the personal experience of many years.

A glazed earthenware pan two feet across, or if preferred, a large bell-glass aquarium should be provided. Then sufficient pebbles from the sea-shore should be taken to cover the bottom of the pan or glass. If they are taken direct from the sea-shore they can be used at once; if other stones are used, it is as well to boil them before putting them in the aquarium. Fill the aquarium with sea-water; this can most easily be brought home in clean quart wine bottles firmly corked.

Now the first essential is to get the water into a healthy condition. This requires a little patience and may at first seem tedious, but when once done one is well repaid for the trouble.

It is best to put nothing into the water but a small quantity of healthy green seaweed—*Ulva* or *Cladophora* answer very well—and two or three periwinkles.

Then buy two specific gravity balls[1]; one, the clear glass bulb, floats on the surface of the water; the green one sinks. A small glass or zinc syringe will also be wanted. Every morning the water must be well syringed; if the green bulb begins to rise to the surface this means that evaporation has taken place—that the water is too salt, its specific gravity is greater. To remedy this, add very slowly a syringe-full of rain, distilled or boiled water until the green bulb sinks. If too much water be added the white bulb will begin to sink.

After a few days add one specimen of the sea-weed which you wish to observe. If a red seaweed, it is best to select a plant growing on a rock or shell, or if this cannot be found, chip off a piece of rock, with the plant attached, with a hammer and chisel. It may happen that one wants to keep a seaweed washed up by the sea, which has been torn from its attachment; in this case tie it to a stone with silk and insert it carefully amongst the other stones. It is well, if possible, to avoid seaweeds which are very rapid growers; those plants which grow naturally below low water mark are the easiest to cultivate.

When the first plant is properly established more may be added.

The great thing to remember is, that nothing must be allowed to *decay* in the aquarium. Dead sand-hoppers and shrimps must be carefully removed with forceps, or the experiment will end in failure.

Another point is: *do not change the water.* The same sea-water will last for years, if its specific gravity is kept right by adding fresh water to compensate for evaporation, At the most, draw off the water once a year with a syphon and re-fill with fresh sea-water.

The aquarium must not be kept in the sun, though a little sunshine occasionally is of advantage. The periwinkles will eat off the green spores, which settle on the glass, especially in sunlight, and will also help generally to keep the water sweet. Their number must be regulated according to experience; enough must be kept to keep the green spores in check.

How to germinate red sea-weed spores. Plant a healthy female plant of red sea-weed (I have tried several species of *Polysiphonia* successfully). It is very important to be quite sure that one's plants are correctly identified and it is also well to get to know the spores of the plant worked with by sight, as it is almost impossible to avoid getting other red-seaweed spores introduced into the aquarium. It is even more important to be able readily to distinguish the tetraspores. These germinate as a rule much more freely than the sexually produced carpospores.

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[1] These can be obtained at Negretti & Zambra's, 38, Holborn Viaduct, E.C.

When the female plant is well established introduce a male plant with antheridia. Spores will readily form, and the fertilization can be observed. When the spores appear ripe prepare some small ½-in. squares of mica and suspend them by silk threads to a transverse section of an ordinary bottle-cork. The cork will float on the surface of the water and the mica square should be so arranged as to hang suspended among the fruits. These mica squares will soon have spores fall on them which will attach themselves by a foot. It is as well only to allow two or three spores to each mica plate. These can be removed at will from the aquarium and can be examined under the microscope so that the whole growth can be watched and drawn. If other spores of green or brown algae settle on these plates they are easily recognised, and can be removed with a piece of cotton wool fixed on a match end.

It is necessary to see that the periwinkles do not climb up the seaweed and eat the spores on the mica, but a very little care in hanging the mica plate will prevent this.

The second year of observation is much more interesting than the first, as one can watch the development of the antheridia and of the young fruits on our two plants, and one has the satisfaction of knowing that they are really healthy normal plants with which we are dealing, whereas a plant taken from the sea and just kept in sea-water without any care, is really degenerating, and observations made on it are really observations on a dying plant.

RINA SCOTT.

May, 1902.

NOTE ON THE ALLEGED DELAY IN GERMINATION OF THE SEEDS OF CERTAIN EUPHORBIAS.

I WAS asked by Mr. I. H. Burkill, F.L.S., to experiment on the germination of some seeds of *Euphorbia Peplus* L., which he had kept for some years; and the results seem to be of interest.

Previous experiments with Euphorbia seeds had appeared to point to a long delay before germination; the facts being contained in a paper of Winkler's in *Ber. d. deutsch. bot. Gesellschaft,* Bd. I. p. 452, and quoted by Wiesner in his "Biologie der Pflanzen."

Winkler states that seeds of *Euphorbia cyparissias* (a perennial), sown in the spring following the autumn in which they ripened, refused to germinate before the lapse of four to seven years, the majority germinating after seven years; and seeds of *Euphorbia exigua* (an annual) did not germinate until nine years had passed. My experiment shows that no such delay is necessary in one species of *Euphorbia* and also that the seeds retain their vitality for a number of years. The seeds in question were put up in a packet, dated December 14th, 1892, and as I sowed them on March 30th, 1901, they were then nearly nine years old, having probably ripened during the summer of 1892. The method of sowing was this:—I divided the seeds into four portions of about ten seeds in each and sowed them in pots. Nos. 1 and 3 were sown dry, in Nos. 2 and 4 the seeds were soaked in water for 48 hours beforehand. Pots 1 and 2 were placed in a hotbed, and pots 3 and 4 were sunk in the open ground.

TABLE OF APPEARANCE OF SEEDLINGS.

1 In heat, dry.		2 In heat, soaked.		3 In ground, dry.		4 In ground, soaked.	
No.	Date.	No.	Date.	No.	Date.	No.	Date.
1	19 April	1	19 April	2	20 May		
3	22 ,,	1	22 ,,	2	5 June		
2	1 May	2	26 ,,	5	1 July		
2	14 ,,	2	30 ,,				
		3	14 May				
8		9		9		0	

The table shows the order in which the seedlings appeared. The first result of the experiment was to show that the vitality of the seeds was unimpaired. Many annuals germinate in heat in two to six days; those took twenty to forty-five days, while those in the open ground took fifty-one to ninety-three days. Only one seedling died; the rest grew into strong healthy plants, and by the middle of August had not only ripened their seeds, but were already surrounded by seedlings which must have germinated shortly after the seeds had fallen to the ground. The second noticeable result was that none of the seeds in Pot 4 germinated. I am inclined to think that I contributed to this failure by having soaked the seeds and then exposed them to the cold frosty ground in their moistened state. They must have been frozen and then rotted in the ground, as I could find no trace of them when I turned out the soil in August. I generally find that soaking hastens germination in leguminous and other seeds, but it did not have this effect on the Euphorbia seeds sown in the hotbed. I had now shown that seeds of *Euphorbia Peplus*, an annual, will germinate readily in suitable conditions after being kept dry, in the air, for several years, and also that they will germinate as soon as sown. It remained, therefore, to make the experiment more complete, to show whether the seeds would germinate as readily after having been kept through the winter, and when they would be in a state of rest. Accordingly I gathered some seeds last autumn and sowed them in a hotbed on March 26th, 1902, and the seedlings began to appear on April 16th, and continued to do so at intervals of a few days, beginning twenty-one days after they were sown. It is clear, therefore, that there is no compulsory dormant period inherent in these seeds; and one asks: does it exist really in any seeds? How can the seeds of the annual, *Euphorbia exigua*, have resisted for nine years? Is there any guarantee that for nine years the necessary conditions for germination, *i.e.* warmth and moisture, were always present? Each year I grow a large number of annual and perennial seeds for the garden. Annuals I have invariably found to germinate the same season, and most perennials do the same. A few species I have found require a whole year in the ground, *e.g. Paeonia corallina.* The delay is usually owing to the presence of a hard testa which requires prolonged moistening, not to any inherent quality in the seed.

ELEONORA ARMITAGE.

May, 1902.

GLYCERINE JELLY AND STAINING.

WHEN making preparations which have to be mounted in Glycerine Jelly, it is often desirable to handle the sections as little as possible and not to prolong the process more than necessary. The following method is simple and effectual and contributes to this end.

It consists of using the mounting medium coloured by means of some aniline dyes so that the sections may be mounted and stained at the same time. This medium is easily prepared by adding a few drops of an aqueous solution of the dye required to warm glycerine jelly, till it is moderately coloured. Sections of plants when mounted in this glycerine jelly will gradually become stained by a process of slow diffusion.

Safranin used thus is very satisfactory; if the jelly be only faintly coloured, it clearly differentiates the lignified and cuticularized elements, but if the jelly is well coloured, the parenchyma is also stained. It is also adapted for sections of stems or leaves showing fungus tissues such as the Uredineæ, etc., when the byphæ will in many cases be coloured by the stain, as will also the young spores. Gentian-Violet and Hoffmann's Blue are also useful when employed thus in connection with fungal byphæ; the former readily stains all the tissues and the latter more particularly the protoplasmic contents.

In making glycerine preparations of Fungi generally, this method of mounting will be found satisfactory. Many Discomycetes, such as Peziza and Lachnea are readily stained thus and form clear and distinct preparations. But when dealing with Fungi the staining properties will be found to depend much on the Individual Fungus, indeed some forms refuse to be stained at all in this way.

Coloured jelly may also be conveniently employed when mounting sections of Mosses or Hepatics, and Gentian-Violet or Safranin may be used as a general stain. It is also quite suitable for many of the Red and Brown Algæ.

This plan of staining will be found to save much time when a number of preparations are required; and besides this advantage there is less risk of damage to the sections, than when the ordinary method is followed.

A. D. COTTON.

Royal College of Science,
December, 1901.

FUCHSIN-IODINE-GREEN AS A CROSS-STAIN FOR TISSUES.

I have lately found the above, hitherto, I believe, only used as a double nuclear stain, useful in differentiating tissues.

The sections in dilute glycerine are covered while on the slide with a mixed solution of Fuchsin and of Iodine-green in 50% alcohol. Usually two or three minutes are enough to stain them a deep purple. They are then washed in absolute alcohol and transferred almost immediately to clove-oil and Canada balsam, the whole process occupying less than five minutes.

The amount of the differentiation varies as the length of the washing, but I have found it best not to carry this too far.

The lignified and suberized elements are stained a deep red purple, while the parenchyma and unlignified tissues generally have their walls blue.

Sometimes in these latter there is a great variety in the shade of blue, and this corresponds to a morphological difference in tissue; so that in a stele the pericycle, phloem, parenchyma and pith may all have their walls a different shade.

The great advantage of this method is its quickness and the ease with which a hand-cut series may be permanently mounted, as well as the sensitiveness of the different tissues to the stain.

The results are not equally good in all cases, but I have found the method answer admirably with vascular cryptogams and dicotyledonous seedlings.

I am not able to answer for its permanency, though sections stained in this way nine months ago shew little change; but however this may be the method is certainly useful in differentiating vascular tissues very quickly for immediate observation.

E. C.

University College,
June, 1902.

"REDUCTION" IN DESCENT.

To the Editor of the "NEW PHYTOLOGIST."

SIR,

The hypothesis of the derivation of a simple structure from a more complex one in the course of evolution is nowadays used with great freedom in the field of morphological enquiry, and it often enables the biologist to understand the existence of types of organization that cannot well be interpreted as relatively primitive. In very many cases the occurrence of such a "reduction" is as certain as any phylogenetic conclusion can well be; it is superfluous to mention instances, of which many will occur at once to every reader. On the other hand, a too facile use of the hypothesis seems to be a danger in various departments of current morphological speculation, and the present letter is written with the object of calling attention to some aspects of this subject.

Dealing first with the general question, it will of course be admitted that progress from simpler to more complex forms has enormously preponderated in evolution. Without going beyond natural selection as a cause of modification, it is not difficult to understand why this should be so. With certain striking exceptions, increase of bulk gives to the individual organism, other things equal, and up to a certain limit, a greater chance of competing successfully with its neighbours, and also the power of producing a large number of reproductive cells—the two great primary factors in the success of a species. But increase in bulk involves increase in complexity of structure, by the necessary division of labour without which a large body would become unworkable. Hence we have a great primary tendency to increase in bulk and complexity, a tendency which we see realised in the history of evolution of the plant-kingdom as a whole.

Side by side with this, however, other factors come into play. Increasing competition for space and food drives some plants into the holes and corners left by those which have gained the first footing. The adoption of very special modes of life is a further outcome of the competition; and these, as we see in the case of parasites, endophytes and epiphytes—to mention only some of the most general and familiar classes of cases—often lead to a very strict limitation or a considerable reduction of size and complexity.

But in all well-established cases of such reduction, we can, without much difficulty, put our finger on its special cause, at least we can realise in some degree the conditions which have led to the decrease in complexity: and we have no reason to believe that there is any general cause leading to reduction apart from such special conditions.

For these reasons it is submitted that in the apparent absence of such special cause, the hypotheses of relative primitiveness and of reduction do not stand on an equal footing. The former has the logically prior claim, and must be accepted as a working theory, until good grounds can be given for preferring the latter.

In some quarters, however, there has become apparent a disposition to treat the hypothesis of reduction as a mere pawn in the game of morphological speculation, to assume that increase or decrease in complexity are equally likely to have occurred, and that the latter can be freely used without any special attempt at proof, if it happens to be required by a theory based on wholly distinct grounds.

Miss Ethel Sargant's paper on "The Origin of the Seed-Leaf in Monocotyledons," in the last number of this journal, seems to furnish an example of this tendency.

The paper is of great interest for more than one reason. The real relation of the two great groups of Angiosperms—so much alike, and yet so well-characterised—is one of the main outstanding problems of comparative morphology, and any genuine attempt to solve it claims our close attention. At the same time the evidence afforded that detailed and long-continued comparative work at the structure of angiospermous seedlings is likely to have important results is of even greater interest to the present writer, who believes that this hitherto practically untouched field of research opens up great possibilities in various directions.

Before proceeding to criticism of that portion of Miss Sargant's paper to which it is desired to take exception, it may not, perhaps, be considered impertinent to express appreciation of the extreme care and thoroughness of her work, and of the breadth of view displayed in her treatment of the subject, as well as to express the present writer's belief in the important nature of the investigation.

Miss Sargant has come to the conclusion (a conclusion which the present writer has every reason to believe likely to be justified) that the symmetry and general construction of the vascular system of the seedling in the Liliaceæ is a trustworthy phylogenetic character in the evolution of that family; she also finds reason to believe, doubtless on very good grounds, which will be fully published in a short time, that a certain genus, *Anemarrhena*, shews in the symmetry of its hypocotyledonary vascular system a primitive type among the Liliaceæ. There are two opposed collateral bundles in the terminal cotyledon of this plant. These run down into the short hypocotyl, where each divides into two, and the four phloems so formed are continuous with those of the tetrarch primary root. This arrangement suggested to Miss Sargant the possibility that the two opposed cotyledonary bundles might represent the bundles of two distinct cotyledons of a dicotyledonous ancestor. Comparing the arrangement in *Anemarrhena* with that found in *Eranthis* among the Ranunculaceæ (a family with several well-known points of resemblance to the Monocotyledons), Miss Sargant finds an interesting similarity.

In *Eranthis* the petioles of the cotyledons are united throughout their length, and the petiolar cylinder so formed contains two opposed bundles just like those of the single cotyledon of *Anemarrhena*. At the base of the joined petioles is a minute hypocotyledonary tuber, in which the two cotyledon traces split up so as to form four phloems and eight xylems "arranged at fairly regular intervals round the periphery of the tuber." Below the tuber is the primary root, which appears to be normally diarch,[1] a structure, so far as is known, universal in Ranunculaceæ, the plane of the diarch xylem plate being coincident with that of the two cotyledonary traces.

Miss Sargant interprets this structure in the light of *Anemarrhena* as being primitively tetrarch, and supposes that the cotyledonary bundles are, in fact, double, while the primary root is diarch by reduction. This leads to the hypothesis that the Ranunculaceæ have been derived from a common ancestor with *Anemarrhena*, an ancestor with typical tetrarch symmetry, the transition from root to shoot taking place, according to Van Tieghem's first type, in which the four phloems run straight up into the cotyledons, while the xylems divide and then re-unite in pairs within the phloems.

Now the most striking point about the anatomy of the seedlings of the Ranunculaceæ is the extreme uniformity of the arrangement of the primordial vascular strands. Typical root-structure is maintained by the vascular cylinder through the greater portion of the hypocotyl, which averages 1 cm. in length. The two protoxylem strands forming the diarch plate pursue a perfectly uniform course into the cotyledons. The two phloems each divide into two and the halves pass laterally outwards, eventually joining external to the protoxylems to form the two collateral bundles of the two cotyledons. Normal stem-structure, so far as the primordial cotyledonary traces are concerned, is nowhere found in the hypocotyl, but if we consider the bases of the cotyledons it is evident that the transition conforms exactly to Van Tieghem's third type. There is absolutely nothing to suggest primitive tetrarchy.

It is no doubt just possible to interpret the phenomena in the way suggested by Miss Sargant. After the structure just described has been laid down, there is formed, at the sides of the diarch xylem-plate, a certain amount of metaxylem which is sometimes even produced by a cambium. This metaxylem often reinforces the primitive protoxylem strand of the cotyledon trace, passing off laterally[1] immediately within the primary phloems at a later stage of development, and being continuous with the metaxylems of the cotyledonary bundles. These metaxylem "wings" evidently correspond to the xylems of the four bundles represented in Miss Sargant's Fig. 10, and on the hypothesis of reduction would represent the two protoxylems of the root-stele which are supposed to have disappeared. But of the supposed primitive division of the first formed cotyledon traces themselves there is, in the majority of genera, no indication whatever.

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[1] There are, however, occasionally indications as of two additional protoxylems in the plane at right angles to the plane of the diarch plate, *i.e.*, immediately internal to the phloems.

We are asked, in fact, to accept a hypothesis of reduction of the primordial hypocotyledonary stele solely on the evidence of a single type with a tuberous hypocotyl, a structure quite exceptional in the family, as against what seems the plain interpretation of the perfectly normal hypocotyls of the other genera. No special cause is adduced to account for such a reduction. Surely the more natural alternative is to suppose that the peculiar vascular structure of *Eranthis* is a direct outcome of its peculiar hypocotyl, the wings of the diarch stele being isolated in their upward course through the swollen hypocotyl, while the two original protoxylem strands split into four, to join again at the top of the tuber.

We can hardly consider an arrangement found only in connexion with an admittedly modified structure as primitive, and explain the arrangement found in the rest of the family as "reduced," without very strong independent evidence for such hypothetical reduction.

I am, Sir,
Yours, etc.,
University College, June, 1902. A. G. Tansley.

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[1] Spiral tracheids are often formed at the inner limit of these metaxylem strands in the upper part of their course, but this phenomenon seems to be simply in connexion with the continued elongation of the hypocotyl after these strands have begun to develop.

A REVISION OF THE CLASSIFICATION OF THE GREEN ALGÆ

BY

F. F. Blackman,

University Lecturer in Botany, Cambridge.

AND

A. G. Tansley,

Assistant Professor of Botany, University College, London.

(*continued from page* 120.)

6. *Struvea*. Sonder, 1845.

Thallus consisting of an erect stout unseptate stalk, terminated by a symmetrical frond of definite form which is made up of a very regular system of septate filamentous branches fastened together to form an open network by rhizoid-like attachments ("tenacula") at the points of contact.

7. *Microdictyon.* Decaisne, 1839.

Thallus a thin sheet of indefinite outline attached by rhizoids at its centre and composed of septate branches, all in one plane and united by tenacula to form an irregular network. Cells all of similar size.

8. *Boodlea.* Murray & De Toni, 1889.

Thallus a spongy mass of septate filaments branching irregularly in all directions and united together by tenacula.

9. *Cystodictyon.* Gray, 1866.

Thallus resembles that of *Microdictyon*, but differs in that the branch system is differentiated into long and short cells.

10. *Anadyomene.* Lamouroux, 1812.

Thallus irregularly frondose and attached by a very short stalk; composed of a system of septate branches with long and short segments united in a plane without any interspaces and often clothed on both faces with an additional layer of isodiametric branch-segments united to form a pseudo-epidermis. Zoospores observed.

****Thallus secondarily septate, of many segments, but not developing as a branch system.

11. *Dictyosphaeria.* Decaisne, 1842.

Thallus when adult a very irregular basin-shaped or flat layer of large hexagonal cells closely united by tenaculum-cells. Secondary series of small cells may occur along the lines of juncture of the hexagonal cells. The thallus arises by the successive subdivision of the protoplasmic contents of an embryonal globular cœnocyte to form a solid mass of compressed cells, which, by growth, becomes hollow and then bursts.

Fam. VIII. GOMONTIACEÆ.

Thallus a minute, radiating, septate, *branch-system. Reproduction* by *zoospores* and by swollen *aplanosporangia, which may be detached and live* for a time *independently.* Marine.

Genus.

1. *Gomontia.* Bornet and Flahault, 1888.

Thallus dorsiventral, growing in the substance of shells and sending down perforating rhizoids. "Cells" contain

1-5 nuclei. Sporangia arise by the swelling of single thallus-"cells" and attain a very large size, usually developing adventitious rhizoids. The contents may divide to form (a) many bi-flagellate zoospores which germinate into a new thallus, or (b) a few large aplanospores which germinate *in situ* or after escaping

[The unique sporangia and the specialisation due to the peculiar habitat leave the exact affinities of this genus obscure.]

Fam. IX. CLADOPHORACEÆ.

Thallus filamentous, branched or unbranched, *abundantly septate* with *two or more,* often many, *nuclei to each segment.*

Chromatophore a perforated parietal plate or a network of polygonal discs. Pyrenoids many. *Reproduction by* bi-or-quadri-flagellate *zoospores, akinetes* or bi-flagellate *isoplanogametes.* All the genera except *Pithophora* are marine.

[By Schmitz and other algologists this family is held to be derived from the filamentous branched Valoniaceae, and the strong similarity of the cytological characters of *Cladophora* with those of *Microdictyon, Siphonocladus,* etc., certainly supports this view. If *Cladophora* is the primitive form, the simple almost unbranched genera with but few nuclei in each segment must be regarded as reduced forms.

Usually, however, the unbranched forms in any mixed family are the primitive ones, and it is possible that in this case they have been derived from an unbranched filament of the Ulotrichoid type by increasing suppression of the formation of septa between dividing nuclei. Wille's account of the simplest species of *Rhizoclonium* strongly supports this view. Further cytological investigations may decide between these theories, but at present systematists are agreed that it is hardly possible rigidly to separate *Cladophora* from *Rhizoclonium.*]

Genera.

1. *Urospora.* Areschoug, 1866.

   Filament usually unbranched, the attachment strengthened by endo-mucilaginous rhizoids. Nuclei several. Zoospore quadri-flagellate.

2. *Chaetomorpha.* Kützing, 1845.

   Filament unbranched, attached when young by a long "cell" with branched unseptate free rhizoids. Segments broad. Nuclei several. Zoospores bi-flagellate.

3. *Rhizoclonium.* Kützing, 1843.

   Filament creeping, usually unbranched, but bearing free rhizoid-outgrowths from some of the "cells"; attached when young by a basal cell. Segments narrow. Nuclei 2—4, occasionally one.

4. *Cladophora.* Kützing, 1843.

   Filaments more or less branched, free or in clumps, the attachment strengthened by endo-mucilaginous rhizoids. "Cells" large with very many nuclei and a network of discoid chloroplasts. Zoospores quadri-flagellate. Isogametes bi-flagellate.

5. *Pithophora.* Wittrock, 1877.

Habit of *Cladophora.* Zoospores not found. Reproduction by akinetes. Exists only in fresh water.

Fam. X. SPHAEROPLEACEÆ.

Filament unbranched, *never attached.* "*Cells*" *very long with many nuclei.*

Reproduction by *oogamy, many eggs* being formed *in each "cell."* *Zoospores never formed* by the "cells" of the thallus.

Genus.

1. *Sphaeroplea.* Agardh, 1824.

"Cells" with nuclei and chloroplasts arranged in irregular rings separated by vacuoles. Nuclei 18—60. Any "cell" may become a gametangium without change of form. Antherozoids tapering, with two flagella, penetrating the wall of the oogonium through round holes. Eggs spherical, with a colourless receptive spot The oospore germinates to form one or more bi-flagellate swarmers which elongate to tapering vegetative filaments without becoming attached.

[This genus has so many unique characters that it stands quite isolated. The large number of nuclei in the cell is practically the only reason for its present position.]

Series III. **Ulvales.**

Thallus composed of uninucleate cells, parenchymatous, membranous, erect, and when young, attached at one point to the substratum by rhizoids. Chloroplast single, a parietal plate, or massive, filling most of the cell.

Reproduction by bi- or quadri-flagellate zoospores and by biflagellate isoplanogametes, arising from unspecialised cells of the thallus. Zygote germinating at once; embryonic forms various.

Fam. I. ULVACEÆ.

Characters of the series.—All the forms are marine.

Genera.

1. *Monostroma.* Wittrock, 1866.

Thallus at first a bladder and usually splitting later to an irregular foliaceous membrane which may float freely. Embryonic form a hollow sphere. Cells irregularly distributed in a single layer. Gametes and zoospores observed.

2. *Ulva.* Wittrock, 1866.

Thallus foliaceous, usually attached by a short stalk. Embryonic form a short filament which broadens out. Cells polygonal, in close contact, arranged in two definite layers. Gametes and zoospores observed.

3. *Letterstedtia.* Areschoug, 1850.

   Thallus of the same structure as in *Ulva*, but growing out pinnately into numerous membranous lateral lobes of limited growth. Sporangia only occurring on the lateral lobes which are shed when old.

4. *Enteromorpha.* Harvey, 1849.

   Thallus a regular or irregular, large or small, branched or unbranched tube, usually floating freely when adult. Cells in one layer, arranged with slight regularity, embryonic form a two-layered membrane which splits to form the tube; the embryonic form is some times persistent at the growing apex.

5. *Ilea.* J. G. Agardh, 1883.

   Thallus similar to that of *Enteromorpha*, but unbranched and always attached, usually of a brownish colour. Cells arranged in very regular lines.

Series IV. **Ulotrichales.**

Thallus of uninucleate cells, consisting typically of branched or unbranched uniseriate filaments. Reproduction by zoospores, by isogamous or oogamous gametes, and by aplanospores and akinetes.

Fam. I. ULOTRICHACEÆ

Thallus consisting of *a single unbranched cell-thread*, fixed to the substratum by a (usually) specialised basal cell. *Chromatophore a single parietal plate.*

Reproduction by 4- or 2-flagellate *zoospores*, and by *2-flagellate isogametes*; also by aplanospores and akinetes.

Genera.

1. *Ulothrix.* Kützing, 1833.

   Cells all equivalent with the exception of the specialised fixing cell. Chromatophore parietal, flat, incompletely lining the longitudinal wall, and containing one or more pyrenoids. Reproduction by zoospores with 4 or 2 flagella, and by biflagellate isogametes. Germination of zygote indirect. Aquatic forms.

2. *Hormidium.* Kützing, 1843.

   Specialised fixing-cell absent. Chromatophore as in *Ulothrix*. Multiplication by fragmentation of the thallus into short lengths or into single cells. Reproduction also by akinetes, and by biflagellate zoospores. Gametes unknown. Aerial forms.

3. *Uronema.* Lagerheim, 1887.

   Thallus fixed by a hemispherical basal disc. Chromatophore parietal with uneven margin, containing (usually) two pyrenoids. Reproduction by 4-flagellate zoospores and aplanospores. Gametes unknown.

4. *Binuclearia* Wittrock, 1886.

Thallus with no distinction between apex and base. Older transverse cell-walls considerably thickened, Chromatophore ring-shaped with no pyrenoid and producing oil. Reproduction by akinetes, which germinate *in situ*. Motile cells unknown.

[It is very doubtful if this genus is correctly placed here.]

Fam. II. PRASIOLACEÆ.

Thallus *a simple unbranched thread or band-shaped to leaf-like by longitudinal division of the cells*, any of which may produce a rhizoid. *Chromatophore central, star-shaped*, with a single central pyrenoid.

Reproduction by the formation of akinetes and aplanospores. Motile cells unknown.

Prasiola. C. A. Agardh, 1821.

Characters of the family.

[This genus, in which *Schizogonium*, Kützing, is included, is often placed in Ulvaceæ, but it seems much more probable that it has descended from a filamentous form.]

Fam. III. MICROSPORACEÆ.

Thallus an unbranched, free-floating filament.

In the growth of the cell-wall the freshly formed layers are not continuous along the length of the cell, but are so laid down that the filament separates into "*H-pieces*," each corresponding with the halves of two adjacent cells, at the escape of the zoospores. *Chromatophores several in a cell, band-shaped, constricted at intervals. Pyrenoids absent.* Zoospores 4-flagellate. Gametes (?) biflagellate.

Microspora. Lagerheim, 1888.

Characters of the family.

[This genus has been placed in a separate family on account of its peculiar characters. Its immediate affinities are not clear.]

Fam. IV. CYLINDROCAPSACEÆ.

Thallus of an unbranched filament, attached when young. Cell-walls thick, often shewing layering. Chromatophore parietal with a single pyrenoid.

Reproduction by biflagellate zoospores of two sizes, by akinetes, and *by antherozoids and eggs, which are developed from ordinary vegetative cells.*

Cylindrocapsa. Reinsch, 1867.

Characters of the family.

[The immediate affinities of this genus are obscure.]

Fam. V. CHAETOPHORACEÆ.

Thallus always attached, usually epiphytic or endophytic, *composed of an attachment-plate of concrescent branched cells and of erect branches* more or less developed, which *usually* bear or are *replaced by 'hairs,' 'setae' or 'filar processes.'* Cells elongated, or polygonal by compression.

Chloroplast a single parietal plate of irregular form, which may be locally thinned or perforated, and in a few cases may be broken up into a number of separate discs. Pyrenoids present.

Reproduction typically by quadri-flagellate zoospores arising in zoosporangia, which closely resemble the vegetative cells, *and* also *by bi-flagellate isoplanogametes.* The occurrence of mega- and micro-planogametes has, however, been proved for one genus. Akinetes and palmelloid stages are usual.

[This family contains a large number of genera often not sharply separable, which seem to form a series in which the branch-system became more and more reduced from the *Stigeoclonium* type—with a small attachment-plate and abundant erect branches—to forms which consist only of a small plate without any free branches. The branches become reduced, successively, in this series to (1) true "hairs" (a sequence of one or more tapering elongated cells with nuclei, and poor in chlorophyll) then to (2) "setae" (long tapering extensions of cells with a definite lumen and containing protoplasm but no nucleus or chlorophyll, and only secondarily shut off from the cavity of the generating cell by local swelling of the walls) and finally to (3) "filar processes" (which are very fine tapering outgrowths of the *cell-wall* only, mucilaginous in nature, and entirely devoid of lumen or contents). The abundance of these reduced structures is known to be determined by external conditions and some species and genera in their natural habitats have very few or none.]

Genera.

*Thallus with abundant erect tapering branches and attached by a small basal plate of coherent branches to a substratum; rarely epiphytic. End-cells of branches always tapering and poor in chlorophyll.

1. *Stigeoclonium.* Kützing, 1843.

Thallus form very variable, devoid of a main axis, branching of erect part is lateral and irregular; branches all quite free and without mucilaginous investment. Chloroplast a parietal band lining all or part of the cell-wall. Reproduction by quadri-flagellate zoospores and bi-flagellate isogametes.

2. *Chaetophora.* Schrank, 1789.

Thallus an erect branch system, without a main axis, imbedded in dense mucilage which may be cushion-shaped or foliaceous and lobed. All branches end in very long tapering colourless cells.

Reproduction by bi-flagellate zoospores alone observed.

3. *Draparnaldia.* Bory, 1808.

Thallus a straggling erect branch system with an obvious main axis on which tufts of small lateral branches with tapering ends are borne regularly. The cells of the main axis are very large and the chloroplast only occupies their central zone.

Reproduction by quadri-flagellate zoospores alone observed.

**The upright branches few and only slightly branched, the basal plate preponderating. Branches sometimes ending in unicellular hairs.

4. *Endoclonium.* Szymanski, 1878.

Thallus-form various, usually an irregular basal plate of polygonal cells, produced by concrescence, and bearing erect or ascending free branches which may end in unicellular hairs. Epiphytic or endophytic. Quadri-flagellate zoospores and bi-flagellate gametes (?) occur.

5. *Pseudendoclonium.* Wille, 1901.

Thallus epiphytic, a small irregular basal plate with upright or rhizoid-like free branches of one or a few cells; no tapering branch-ends. Chloroplast a parietal plate only occupying a small part of the cell.

Zoosporangia round and opening with a very short neck. Zoospores quadri-flagellate without eyespots.

6. *Epicladia.* Reinke, 1879.

Thallus abundantly branched, the central part cohering to a pseudo parenchymatous plate, the peripheral branches free and without tapering ends. Chloroplast may line the whole cell. Reproduction by zoospores.

*** Thallus an irregularly branched, creeping, endophytic, elongated axis, bearing short erect branches, which end in hairs or setae.

7. *Chaetonema.* Nowakowski, 1876.

Thallus an elongated sparsely branched creeping endophytic axis bearing short erect branches which terminate in unicellular hairs. Cells elongated not crowded. Quadri-flagellate zoospores alone observed.

8. *Bolbocoleon.* Pringsheim, 1862.

Thallus an elongated endophytic axis bearing numerous short erect branches, all the cells of which bear setae. Zoospores bi-flagellate.

9. *Acrochaete.* Pringsheim, 1862.

Thallus as in *Chaetonema*, but the erect branches are very short and unicellular, or only unseptate processes. Branches end in setae, with a thickened basal wall.

Probably both zoospores and gametes occur.

****Thallus a creeping branched endophytic or epiphytic axis without erect vegetative branches, but bearing erect hairs or setae.

10. *Aphanochaete.* A. Braun, 1851.

Thallus a creeping epiphytic branched axis bearing upright unicellular hairs. In cultures the hairs may revert to ascending branches.

Zoospores of different sizes occur and heterogamy has been observed. The female planogamete is large, round, quadri-flagellate and sluggish, the male is small, pyriform, active, with four flagella and very little chlorophyll.

11. *Gonatoblaste.* Huber, 1892.

Thallus as in *Aphanochaete* but the young cells bearing erect setae which secondarily become occluded and displaced by further growth.

Zoospores quadri-flagellate.

12. *Endoderma.* Lagerheim, 1883.

Thallus very various, a creeping branch system without erect branches, either endophytic with swollen cells straggling branches and no setae or growing as a dense cluster in wall of host, or epiphytic with setae, and ultimately growing to dense cushions by superposition of branches.

Zoosporangium opening by a small tube, zoospores quadri-flagellate and also bi-flagellate (? gametes).

13. *Phaeophila.* Hauck, 1876.

Thallus endophytic or epiphytic, a much branched creeping axis with no erect vegetative branches. Setae one or two to each cell spirally twisted, secondarily occluded. Cells sinuous elongated.

Zoospores emitted through a long tube, and gametes probably also occur.

14. *Ochlochaete.* Thwaites, 1849.

Thallus an epiphytic cushion of compressed branches which may be two or three layered by superposition of branches. Each external cell may bear a seta or very few may be present.

Zoospores liberated through a tube.

*****Thallus a pseudo-parenchymatous disc produced by the concrescence of a branch-system, and without erect branches. Setae or filar processes are usually present.

[Some of the genera placed in this last group have been withdrawn from the family Ulvaceae, which is to be characterised by truly parenchymatous growth and by the restricted attachment of the thallus. All the genera included in the present section grow by concrescence of cell-branches and are attached by the whole surface of the thallus.]

15. *Pringsheimia.* Reinke, 1889.

Thallus an epiphytic plate of a single layer of deep cells very closely coherent with a well defined outline, a general mucilaginous investment and projecting setae (sometimes absent). Bi-flagellate zoospores and gametes occur.

16. *Chaetopeltis.* Berthold, 1878.

Thallus an epiphytic flat regular plate of a single layer of cells in close contact, usually with long filar processes growing out from the cell walls (sometimes absent) and irregularly distributed. The plate chloroplast is so thin in places that it simulates several separate discs. Quadri-flagellate zoospores and bi-flagellate gametes occur.

17. *Myxochaete.* Bohlin, 1894.

Thallus an epiphytic monostromatic plate of closely aggregated polygonal cells each with two filar processes growing from the free wall. Reproduction not observed.

18. *Nordstedtia.* Borzi, 1892.

Thallus of clustered cells growing on bones. The cells bear filar processes which are very long and have a slightly thickened base. Imperfectly known. Chloroplast described as star-shaped.

19. *Ulvella.* Crouan, 1859.

Thallus a well defined lenticular epiphytic plate with several layers of round cells at centre and radiating long cells at the periphery. No setae or filar processes. Zoospores may arise from the centre cells.

Fam. VI. CHAETOSIPHONACEÆ.

Thallus an endophytic cylindrical or swollen *branch-system,* which is *coenocytic in structure,* being either entirely devoid of internal septa or having them only at rare intervals. *Setae* (in the strict sense) *occur* and the *chloroplasts* are *discoid,* when mature, by fragmentation of a parietal plate.

Reproduction by quadri-flagellate zoospores.

Genera.

1. *Chaetosiphon.* Huber, 1892.

Thallus endophytic in *Zostera*-leaves, forming a straggling branch-system, which is constricted at irregular intervals, but only forms septa to delimit the zoosporangia. Erect setae (which may be secondarily occluded) project through the surface of the host. The chloroplasts are angular discs, free or united by fine processes. Nuclei large and moderately abundant, but sometimes only one occurs between two constrictions of the thallus. Zoopsorangium terminal and swollen, liberating the zoospores by a narrow tube which emerges through the surface of the host.

2. *Blastophysa.* Reinke, 1888.

Thallus endophytic, consisting of a chain of large globular vesicles which may be separated by short tubes, or may arise in close contact with one another by 'budding.' The connecting tubes at first contain protoplasm and chloroplasts, but the contents are afterwards withdrawn into the vesicles, and these become occluded by septa from the empty tubes and from one another. In slide-cultures the tubular thallus predominates. Chloroplasts are angular discs, formed by fragmentation and lining the vesicle wall. Setae occur projecting from the host, sometimes in great numbers. The contents of a vesicle may divide into a large number of zoospores, which escape through a narrow projecting tube.

[In constitution, these two genera recall the Siphonales, to which (especially to *Valonia*) they have been related by most authorities. They have, however, so many points (endophytic habit, exactly comparable setae, fragmenting plate-chloroplast, sporangial emission-tube, and quadri-flagellate zoospores) in common with certain genera of the fourth section of the Chaetophoraceae that this seems rather to be their true affinity, and we must consider that their siphoneous thallus is a secondary evolution quite apart from the phylum of the Siphonales. The fact that slide-cultures of *Blastophysa* are but slightly vesicular seems to indicate that the tubular thallus is primitive and the *Valonia*-like swellings only secondary.]

Fam. VII. CHAETOSPHAERIDIACEÆ.

Thallus epiphytic consisting of *a reduced* clustered *branch-system* invested with dense or thin mucilage. Cells globular with a single parietal chloroplast and one pyrenoid. All or some of *the cells bear* each an erect *sheathed seta or sheathed filar processes.* Reproduction not observed, but zoospores undoubtedly occur.

[The three genera now united in this family have been assigned very various systematic positions by the few writers who have worked on them. The view here taken is to regard them as combining the epiphytic reduced branch-system characteristic of the Chaetophoraceae with the truly sheathed setae of the Coleochaetaceae. The accounts of the structure of the setae are not always harmonious. Probably the 'sheath' is in all cases at first an outgrowth of the cell-cavity, then its cuticle becomes ruptured at the apex and the inner layers grow on with a reduced diameter as a seta with a distinct lumen (*Coleochaete*), or with an extremely fine lumen (*Chaetosphaeridium*) or as a filar process quite devoid of lumen (*Conochaete*).]

Genera.

1. *Chaetosphaeridium.* Klebahn, 1892.

Thallus epiphytic, consisting when mature of rounded green cells, united by longer or shorter empty tubes (sometimes hardly detectable) to form a sort of sympodial branch-system. Each green cell is capable of dividing to form two hemispherical cells of which the upper only puts out an erect sheathed seta, while the lower grows out laterally into a tube, the contents of which become aggregated at the growing end and are cut off to form a new green cell. Chloroplast a parietal plate with one pyrenoid. The lateral tubular outgrowth may apparently sometimes function as a zoosporangium, opening at its apex.

[The presence of a central row of stainable granules along the axis of the seta is the only evidence of its having possessed a lumen.]

2. *Dicoleon.* Klebahn, 1893.

Thallus epiphytic, discoid, consisting of a clustered moniliform branch-system, clothed by a thin mucilaginous tubular sheath. Cells globular, some bearing a single seta with a unique double sheath; the outer sheath being short, and the inner one much longer. Reproduction unknown.

3. *Conochaete.* Klebahn, 1893.

Cells globular, not united into filaments, but clustered irregularly within mucilage to form an epiphytic disc. Each cell bears several very long and fine sheathed filar processes on its free surface. Chloroplast a single parietal plate with one pyrenoid. Zoospores (4-8) may arise in an enlarged cell and escape by a short tube.

(*To be continued.*)

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ON SOME POINTS OF APPARENT RESEMBLANCE IN CERTAIN FOSSIL AND RECENT GYMNOSPERMOUS SEEDS.

By F. W. OLIVER.

Of the considerable number of fossil seeds with whose organisation we have become acquainted through the labours of French and of English palaeo-botanists, none shew a higher degree of complexity than *Pachytesta* from the French Permo-carboniferous, and *Lagenostoma* from the Lower Coal Measures of Lancashire. In the present note it is proposed to direct attention to some of the complex features shewn by the two seeds just named whilst some reference will be made to *Torreya*, an existing genus of Taxaceae.

Of known palaeozoic seeds many seem to be organised on what may be quite generally termed the Cycadean type. Such seeds are straight, the upper portion of the nucellus is transformed into a pollen chamber of varying magnitude, whilst the integument (often bearing an outer sarcotesta) is adherent to the nucellus throughout the prothallial region. In other words the pollen-chamber and the micropylar region of the integument alone are free from one another. Treub,[1] who drew a comparison between this type of ovule and the sporangium of *Ophioglossum*, has expressed the view that these free portions are new developments.

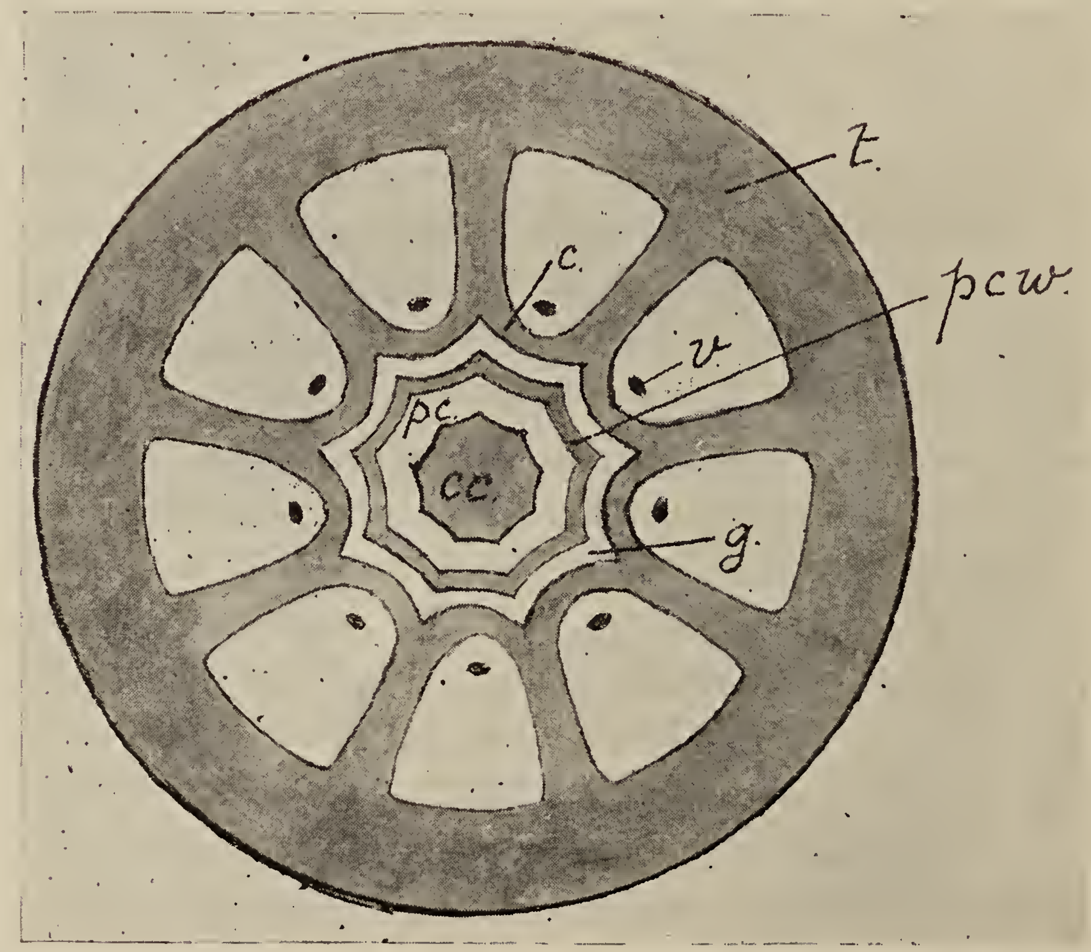
In other palaeozoic seeds, of which *Stephanospermum akenioides*, Brongn. may be cited as an example, nucellus and integument appear to have been free, from the chalaza upwards. This condition may be regarded as more primitive, and the adnate Cycadean type as derived from it by the intercalation of an extensive basal region (phylogenetically younger) in which the prothallium and embryo find accommodation. Whatever view may be taken of the Cycadean

[1] Ann. du jard. bot. de Buitenzorg, vol. II., p. 48. "Le Nucelle et le tégument seraient des créations nouvelles dont on ne trouve pas d'homologues dans les cryptogames."

seed the same anatomical regions can be discriminated in the free and in the adnate regions. In the latter we find downward prolongations of the various integuments and layers of the free apex, of the fleshy and bony layers of the integument as well as of its inmost soft lining, of the nucellar wall and embryo-sac.

Consequently two types of seeds may be recognised. The Stephanospermum type with a free or "superior" nucellus; the Cycadean type with adnate integument, the nucellus of which might be termed "semi-inferior." This explanation is necessary to render what follows intelligible. It is not intended in the following pages to consider more fully the relations of these types of seeds. The points raised affect characters visible in transverse sections in the three seeds *Lagenostoma*, *Pachytesta* and *Torreya*. They may be conveniently treated in this order, which is that of their relative antiquity.

Lagenostoma, Will.



Text figure 4.

Transverse section of *Lagenostoma* cut near the micropyle. The section traverses the pollen-chamber *pc* enclosed in its wall *pcw*; *cc* is the central cone of nucellar tissue which rises up from the base of the pollen-chamber; *t*, testa, the outer third of which consists of a palisade layer; *c*, the fluted "canopy," a characteristic structure within the testa surrounding the free part of the nucellus (pollen-chamber); *v*, vascular strands running longitudinally in the chambers of the "canopy"; *g*, chink between the "canopy" and pollen-chamber wall (× 25).

This seed, best known from Williamson's full and admirable description[1] of *L. ovoides*, occurs in beautiful preservation in the calcareous nodules of the Lower Coal Measures. It is a small seed (5 or 6 m.m. × 4 m.m.) belonging to the type with adnate integument and nucellus. It is only in the pollen-chamber region (about $\frac{1}{5}$ the whole length of the seed) that these parts are free from one another. The relations of the parts in longitudinal section are shewn in Williamson's figures[2].

The free apex of the nucellus, the "lagenostome" of Williamson, is transformed into a pollen-chamber. The nucellar epidermis persists as the wall of the chamber (*pcw* in text fig. 4) whilst the cavity of the pollen-chamber arises by the breaking away of the central tissue from the wall. This central mass stands up as a cone of tissue (*cc*, fig. 4) on the floor of the chamber, the actual pollen-chamber, in which pollen-grains are frequently found, is in a bell-shaped crevice (*pc* in fig. 4) which communicates with the exterior at the micropyle. This form of pollen-chamber is very remarkable and perhaps unique.

The wall of the pollen-chamber is longitudinally ridged, these ridges are seen in the transverse section as projecting cusps. The central cone which has become separated from the wall in the development of the pollen chamber has corresponding radial projections. In the specimen upon which the accompanying diagram is based, nine symmetrically placed ridges are present.

Surrounding the pollen-chamber is the very complicated integument, consisting of an outer zone (*t*) which is circular in transverse section, and an inner zone consisting of nine symmetrically disposed chambers which are separated from one another by strong radial plates. The internal angle of each chamber is convex and their internal containing-walls form collectively a fluted membrane, the relations of which are well seen in fig. 4. This membrane (*c*) was termed by Williamson the "canopy." As the figure shews, the cusps or ridges of the pollen-chamber wall interlock with the grooves between the convexities of the canopy. The unshaded space (*g*) between these two membranes is the natural gap between the nucellus and integument, these two portions of the seed being, of course, free from one another in this region. As regards the morphological nature of the canopy and radial plates, the provisional view may be taken that they represent an inner layer of the testa

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[1] On the Organisation of the Fossil Plants of the Coal-measures. Pt. VIII., Phil. Trans. 1877, pp. 233-243, and figs 53-5

[2] loc. cit., figs. 60-69.

(endotesta) much specialised towards the apex of the seed.[1] Below the level at which the nucellus ceases to be free the canopy dies out. The tissue which originally occupied the chambers of the canopy is not preserved with the exception of a single tracheal strand (*v*) in each chamber. These strands are the upward prolongations of vascular strands which run in the zone common to integument and nucellus and which take their origin from the supply bundle which enters the seed at the chalaza. It is not, however, the purpose of the present paper to elucidate the obscure functions of the canopy or to consider the homologies of the vascular strands.

Pachytesta.

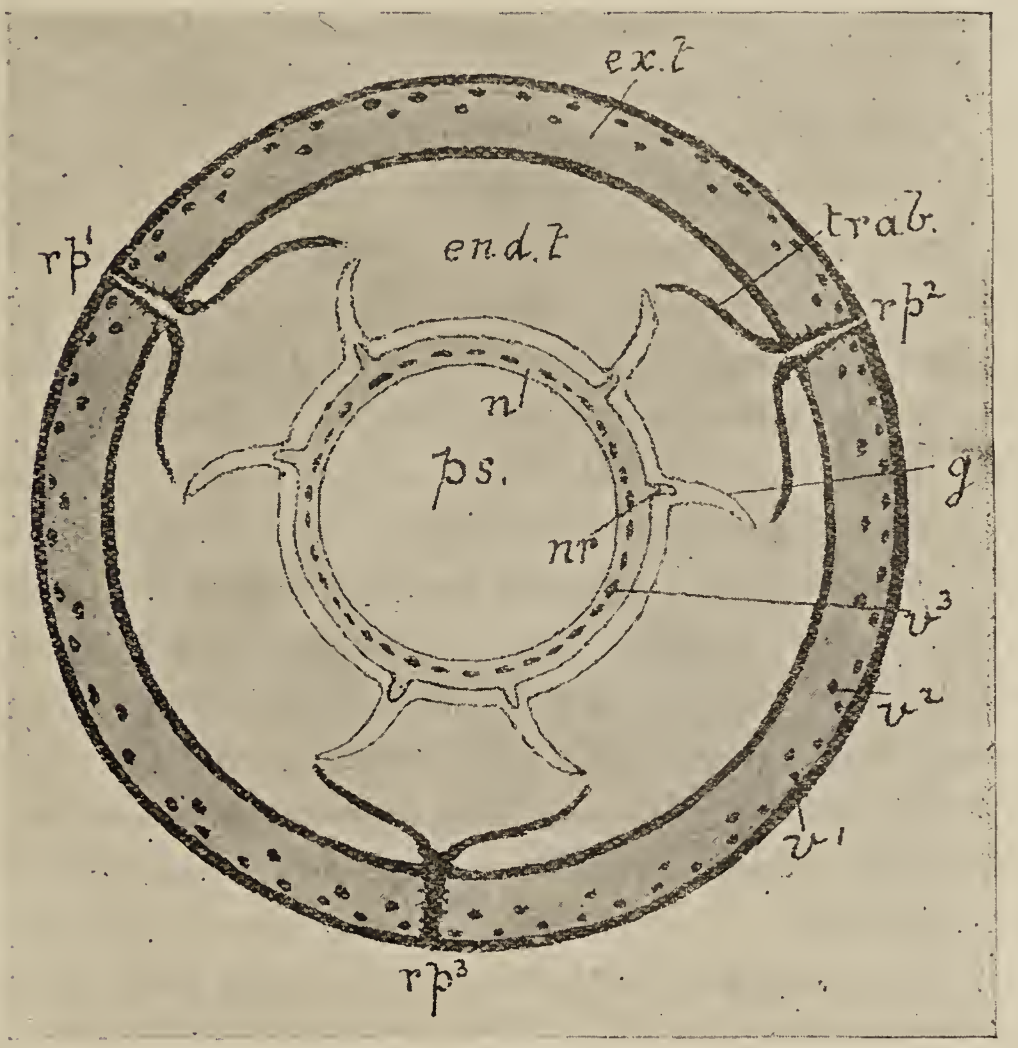
The immense seeds which attained the form and dimensions of a hen's egg, were amongst the most remarkable that have been preserved from permo-carboniferous times. Our knowledge of their organization is due to the investigations of Brongniart[2] and Renault.[3] Separated from the thick testa by a considerable interval there stands the nucellus, raised upon a conspicuous and peculiar chalazal peduncle. The nucellus just as it narrows down to this peduncle is produced considerably beyond the place of its insertion, so that in a longitudinal section the nucellar base might be described as cordate or even reniform. At the summit of the nucellus is a large pollen-chamber, but within the body of the nucellus no prothallium has been found preserved. The vascular supply enters the seed at the base, giving off two successive series of bundles as it traverses the testa. These are very numerous and form a double system near the outside surface of the exotesta. After its passage through the nucellar peduncle the bundle expands into a tracheal plate, the margins of which are continued around the periphery of the nucellus as a number of distinct bundles. The remarkable features of the seed reside in that part which lies between the nucellus and the exotesta, and are only realized on examining transverse sections.

[1] Where the seed-coat is differentiated as a hard outer layer with an inner (often soft) lining, the terms *exotesta* and *endotesta* are employed; where, as in *Cycas*, there is a fleshy outer layer, an intermediate stony layer, and a soft inner layer, they may be distinguished as *sarcotesta*, *sclerotesta* and *endotesta*. Whether an aril, when present, is homologous with sarcotesta is an open question.

[2] Les graines fossiles silicifiées, p. 25, pl B., figs. 4 and 5, and pl. xviii.—xxi.

[3] Flore fossile d'Autun et d'Epinac, p. 389, and pl., lxxxiii. and lxxxiv., figs. 1 and 2.

The annexed diagram (text Fig. 5) represents a transverse section across the middle of the seed based on the information given by Brongniart and Renault. The apprehension of the complex relations of the parts has become a matter of no little difficulty owing to the conflicting nature of the original accounts. Particular reliance has been placed on Brongniart's plate xviii, figs. 1 and 2, and Renault's plate lxxxiii., fig. 5. The diagram is, however, an interpretation based on data lacking somewhat in completeness. The outer dark ring is the exotesta which seems to have consisted of a spongy pitted tissue, limited within and without (the thick dark edges) by sclerotic layers—the whole being perhaps equivalent to sarcotesta and sclerotesta in other cases. At three spots symmetrically placed the sclerotic tissue forms radial plates cutting the testa into three arcs. These arcs separate ultimately into valves by the rupture of these radial plates as at *rp.*^{1}



Text figure 5.

Transverse section of *Pachytesta*, adapted from published figures of Brongniart and Renault. The darker outer zone (*ex.t.*) is the exotesta, with sclerized external and internal bands (black); *end.t.* endotesta with longitudinal grooves at *g*; *rp.*^{3}, sclerotic radial plate of exotesta; *rp.*^{1} and *rp.*^{2} ditto split; (*n*) nucellus with ridges (*nr.*) which engage with the grooves of endotesta (*g*); *ps.*, prothallial space; *v.*^{1} and *v.*^{2} outer and inner series of bundles of the exotesta; *v.*^{3} bundles in the nucellar wall (× 2).

and *rp.*[2] The lowest plate (*rp.*[3]) is shown in its younger unsplit condition. To the inner edge of each radial plate two divergent fibrous membranes or trabeculae (*trab.*) are attached, which, as shown in the diagram, end in close relation with the bottoms of six paired grooves (*g*) in an epidermis-like membrane. The general matrix of this region or envelope of the seed, though preserved in a fragmentary condition, may be safely regarded as having been a continuous tissue of delicate texture. With the grooved membrane what seem to have been ridges on the nucellus engage (*nr.*); whilst in the thickness of the wall of the nucellus there is a circle of vascular cords (v^3). Within, the nucellus is without organic structure. Figure 5 is based on Brongniart's fig. 2, pl. xviii., and Renault's fig. 5, pl. lxxxiii. These two drawings are evidently based on the same preparation, though the interpretation of the parts is different. The facts, as to which there seems no question, are interpreted on the supposition that the region between e^1p and e^1p^1 in Brongniart's pl. xviii., fig. 2, is a soft inner layer of the testa (endotesta) of the existence of which in other seeds adequate evidence is forthcoming.

Briefly, *Pachytesta* seems to have possessed an extensive endotesta (*endt.*) of spongy consistency, this layer was grooved, and with these grooves ridges from the nucellus engaged. In this way, perhaps, the bulky nucellus was supported, and kept adjusted and properly centred. The whole arrangement was strengthened by sclerised trabeculae, which are portions of the endotesta specially differentiated. In essentials, however, there is no structure present not readily derivable from a simple seed like *Stephanospermum akenioides*. That the filling tissue of the endotesta served as floating tissue and that *Pachytesta* was a drift seed, as Renault suggests, seems most plausible. The fact that the relations between testa and nucellus near the apex were more complex and not wholly intelligible as yet—perhaps owing to the forking of the longitudinal furrows and ridges so that they became twelve in place of six[1]—is not material to the argument. We cannot hope for a full knowledge of the structure of this seed till a series of transverse sections of a specimen with unusually good preservation is obtained.

If *Pachytesta* and *Lagenostoma* be compared with one another the points of resemblance are striking. That transverse sections from different heights in the two seeds are being compared, from the pollen-chamber region in the latter and across the middle of the seed in the former, is not a matter of great moment. In the first place both show a bulky zone within the testa, broken up into longitudinal chambers by the intrusion of trabeculae or radial plates. If the trabeculae of *Pachytesta* instead of converging at the points *rp.* ran out radially from the bases of the grooves *g*, and if at the same time the inner containing membrane of the endotesta were indurated, with these slight changes the peripheral regions of the two seeds would be essentially identical in structure. The presence of the vascular strands *v* in the chambers of *Lagenostoma* is the most important difference.

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[1] Renault, loc. cit., p. 392, and pl. lxxxiv., fig. 1.

A second point of agreement resides in the grooving of the endotesta and canopy, and in the interlocking with these grooves of longitudinal ridges on the nucellus. It is hardly an exaggeration to say that both seeds possessed a grooved " canopy " which engaged with longitudinal ridges on the nucellar surface.

What may have been the significance of this contrivance, whether it was of importance mechanically in properly centering the nucellus, or whether it had some other function, is a matter difficult to decide. It is moreover an open question whether the relations that may have existed between nucellus and endotesta at a later stage in the development of these two seeds can be fully realized from the fossils, for like all other palaeozoic seeds they are only known in a stage of development just prior to fertilization. In any case the peculiar relations of nucellus and integument in *Pachytesta* and *Lagenostoma* suggest that this condition, whatever its signification here, may have formed the starting point of those much more complicated foldings which exist between the central and peripheral portions of the seed in the little-known genus *Torreya.* The next section of this paper deals briefly with the nature and origin of these foldings in that genus.

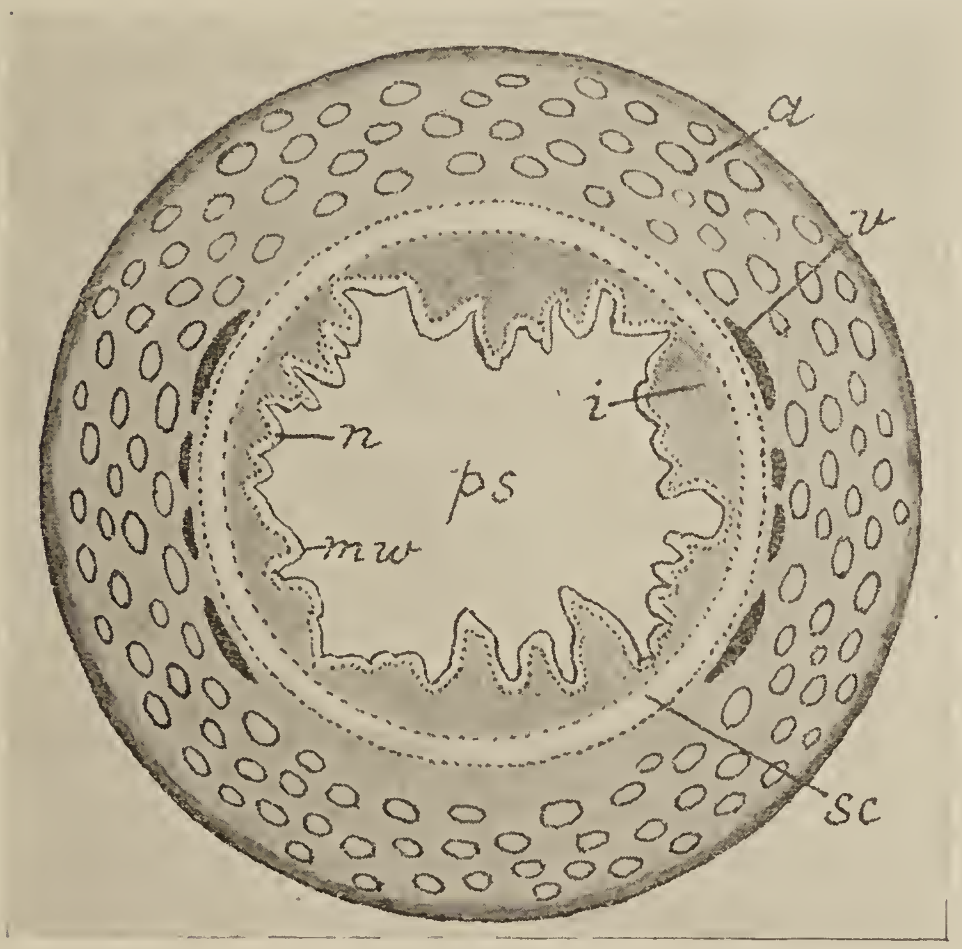
A minor point of agreement in *Lagenostoma* and *Pachytesta* is in the form of the tracheal strands which radiate from the base of the nucellus. These strands running in the nucellar wall of *Pachytesta* are shewn in Brongniart's Pl. xviii., fig. 2, *f*, in transverse section. They are compact and tangentially elongated, having a lenticular section. In good specimens of *Lagenostoma* the characters of these nucellar bundles are essentially the same. Figures of the latter have not however been published. This particular form of strand does not appear to be very common in palaeozoic seeds.

Torreya.

The curious relations exhibited by the seeds described above suggested a comparison with *Torreya*, remarkable as being the only living genus of Gymnosperms known to possess a ruminated endosperm.

The young ovules (which emerge from the bud at the end of May for pollination) if examined in April whilst still immature shew a free nucellus enclosed in a single integument. Early in May a zone is intercalated at the base of the ovule and from this zone the aril subsequently arises. By the winter the ovules are fertilised and the beginnings of embryonic development initiated. The aril has meanwhile grown up to the micropyle. The further extension of the seed is intercalary, so that by the following summer an extensive zone has been added at the base—indeed the whole seed with the exception of its immediate apex originates in this way. In a ripening seed of the second year taken at the end of June, the portion in which nucellus, integument and aril are free from one another, may represent less than $\frac{1}{20}$ the entire length of the seed. In the downward extension of the seed, however, all the parts free above are anatomically distinguishable—nucellus, integument and aril. The transverse section represented in fig. 6 being across the *middle* of a seed taken at the end of June in its second year, the various layers are consequently continuous with one another.

The outer, shaded zone *a* represents the aril with its numerous gum-canals. At *v* (in black) are the two sets of vascular bundles which in this region of the seed belong to the aril. The unshaded ring *sc* corresponds with the outer part of the integument. It is the zone in which the stone or sclerotesta will subsequently differentiate. The shaded belt *i* is continuous with the inner part of the integument, so that *sc* and *i* together may be regarded as the equivalents in the body of the seed of what is a free integument above. Within the integumental region is a colourless border *n*, this is the downward continuation of the nucellus. The containing line *mw* marks the edge of the prothallium, the central area *ps* being occupied by the (at this time) translucent, watery endosperm. Well marked foldings between the inner portion of the integument (*i*) and the nucellus (*n*) are already present. Actually a number of longitudinal ridges, due to the active, localised, inward growth of the integument in a radial direction, are present though they have not yet attained their full dimensions. These ridges are the rumination plates which form so conspicuous a feature in the ripe seed and by the agency of which the endosperm is divided and sub-divided into bays. The intrusive ridges run mainly in a longitudinal direction though they occasionally anastomose. The internal edges of these ridges are not straight but sinuous, so that in radial section a ridge shows a number of irregular, alternating summits and depressions. Whilst the integumental region in this way invades the prothallial area, this latter undergoes radial extension between the ridges. The area of contact of the two active tissues is thus continually increased and it is difficult to avoid the conclusion that rumination plays an important part in the nutrition of the endosperm. In this connection the distribution of chlorophyll in the transverse section of the seed is instructive. This is shown by the shading in text figure 6. The aril is coloured green throughout, the pigment being deepest at the periphery. The containing epidermis is richly provided with stomata and all the conditions necessary for an effective assimilating apparatus would seem to be present. The outer zone of the integument (*sc*) which will form the stone or sclerotesta is colourless, but its inner layer (*i*) is provided with chlorophyll. The narrow nucellar zone (*n*) and the prothallium are also colourless, but of course the intrusive radial plates bring chlorophyll-tissue



Text figure 6.

Transverse section of ripening seed of *Torreya nucifera* cut midway between attachment and micropyle. Aril, integument and nucellus are all confluent in this region. The general shade on the outer and inner zones represents the distribution of chlorophyll, deepest (dark shading) at the surface of the aril. *a*, aril with numerous gum canals; *v*, in black, the vascular bundles, here running near the inner limit of the aril; *sc*. colourless outer zone of integument in which the hard shell or sclerotesta will subsequently differentiate; *i*, inner portion of integument (soft endotesta) from which arise the intrusive ridges; *n*, the colourless inner border represents the nucellus in this region; *mw*, wall of macrospore; *ps*, prothallus (× 4½).

into close association with the whole of the internal tissue of the seed, whilst an adequate water-supply is secured through the bundles *v*.

Up to this period of development the rumination is restricted to that portion of the seed which has arisen by intercalary growth below the free nucellus. This region, however, constitutes by far the greater part of the seed. In a ripening seed (June 30th) of 35 m.m. length, a typical instance, the free portion of the nucellus did not exceed 1.5 m.m. in height, whilst the intercalated portion reached 30 m.m. Later, the intrusive folds appear to be carried up into the free portion, but this is probably rather a mechanical necessity than a point of phylogenetic significance. In these "cycadean" seeds the whole centre of activity may be supposed to have been transferred from the free to the secondary ("adherent") portion of the nucellus.[1]

Attention has been directed to the marked resemblance existing between *Pachytesta* and *Lagenostoma*, more especially to the longitudinally running chambers in the endotesta, and to the interlocking of this zone with the nucellus. In *Torreya* these chambers are wanting, whilst an additional integument is represented in the aril. The interlocking of the nucellus with the zone corresponding to endotesta attains, however, a striking development in the intercalated portion of the seed. Can this feature in the last-named genus be regarded as a survival or an advance upon the *Pachytesta* condition? or, is it a mere coincidence like the centripetal wood in *Cephalotaxus Koraiana*[2]? Actually, of course, we know very little about *Pachytesta*, since the only stage found preserved (that figured) is probably anterior to fertilization. Even in that case the interlocking may have been but a stage in a sort of rumination. In *Lagenostoma* the meaning of the interlocking is obscure. It can hardly be interpreted as having been physiologically equivalent to what is termed rumination, though it too may possibly be a curious survival of the condition found in *Pachytesta*. That the beginnings of rumination in *Torreya* are only recognisable long after fertilization has taken place (not till April in the second year when embryos are already forming) is just what might be expected in a modern seed which has become thoroughly adapted to the proper nutrition of its contained embryo.

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[1] The considerations which lead to the belief that the seeds of *Torreya* and other Taxaceae, of Cycads and Cordaiteae, together with many unassigned palaeozoic seeds, belong to plants of common descent cannot be set forth here.

[2] *cf*. This Journal, vol. I., p. 29.

University College, London. *July*, 1902.

COCCOLITHS AND COCCOSPHERES.

By V. H. BLACKMAN.

ALTHOUGH the curious structures known as Coccoliths were first observed in 1836, yet the exact nature of the organisms from which they are derived has remained unsettled till the present year. They were first described by Ehrenberg in various chalk formations, as minute round or oval calcareous plates, and considered to be of inorganic nature. About twenty years later, however, Huxley and Wallich observed similar structures in deep sea deposits, obtained from the North Atlantic in connection with the laying of the first cable between Europe and America. Huxley gave them the name of Coccoliths, on account of their resemblance to a *Protococcus* cell, while Wallich observed that in the deep sea ooze they were sometimes found aggregated into spherical masses, which he called Coccospheres and rightly considered to be the organisms from which the Coccoliths had been derived by the separation of the plates of the skeleton. The Coccospheres themselves, however, he considered to be mere developmental stages of Foraminifera. A few years later the same worker made the important discovery that not only were Coccospheres to be found in the chalk (as Sorby had in the meantime observed) and in deep sea deposits, but also floating free on the surface in tropical waters. It was thus clear that Coccospheres were very ancient forms and of much scientific interest on account of the part which they have played in the production of the chalk and the part they still play in the formation of deep-sea deposits.

Wallich described two species of *Coccosphaera*, and on the Challenger expedition Coccospheres were met with in most waters, except polar ones, together with forms bearing plates of a different shape, to which the name of Rhabdospheres was given. It seemed clear that the Coccospheres and Rhabdospheres were unicellular organisms, but as nearly all observations had been confined to the calcareous skeleton, there was very little evidence as to their systematic position, and the strangest views as to the nature of the Coccoliths were put forward; the actual existence of Coccospheres being doubted by many who had failed to find them. John Murray had suggested that the organisms in question were of algal nature and this was supported by the discovery, in 1897, of a yellow green chromatophore in *Coccosphaera leptopora* by George Murray and Blackman. The small size (10-30μ.), however, of these organisms renders their capture very difficult, for the finest miller's silk available for nets has a mesh of at least 50μ., so that it is only when the meshes become partially blocked that the organisms are caught at all. It is also clear that the treatment which the organisms receive in the nets is very likely to cause the destruction of any flagella or pseudopodia which they may possess; to these two factors was due the scantiness of our knowledge. What was wanted was a more satisfactory means of capture, so that the organisms might be observed unaltered and in the living state. Such a means has lately been discovered by H. Lohmann,[1] and by its means he has been able to settle the much disputed question of their systematic position. His ingenious method consists in taking advantage of the natural filtering apparatus possessed by the Appendicclariæ. The apparatus can be removed from the animals under the microscope, when there are found entangled in its meshes a large number of Protozoa and Protophyta. Under these conditions Lohmann was able to observe Coccospheres in a living condition and to observe the presence of one or two yellow or green chromatophores and of one or two *flagella*. From these observations it is clear that the group formerly known by the name of Coccosphaeraceae must be considered to belong to the *Flagellata*, and it is placed by Lohmann in the division *Chrysomonadina* of that group. He points out that Wallich's genus. Coccosphaera, which formerly gave the name to the group, must be dropped on account of the use, for another organism, of that name by Perty in 1852, in an obscure paper. He proposes instead, the name *Coccolithophora*, and terms the group the *Coccolithophoridae*. Lohmann shows, by means of suitable methods of filtration, that the organisms are much more common in the upper layers of the sea (at least in the Mediterranean, in which his investigations were carried on) than was formerly supposed, and that they play an important part in general marine metabolism, though their numbers of course cannot be compared to those of Diatoms or Peridineæ. He describes eight genera and 22 species, though previously only three genera and 5 species had been known. All the forms are marine, and all are characterised by the formation of a calcareous skeleton, consisting of plates of very various shapes; in the majority of the forms, also, one or two usually yellowish chromatophores were to be observed, and one or two flagella, so that the group is a sharply marked one among the Flagellata. Very interesting results will, no doubt, be obtained by the use of similar methods in other marine areas.

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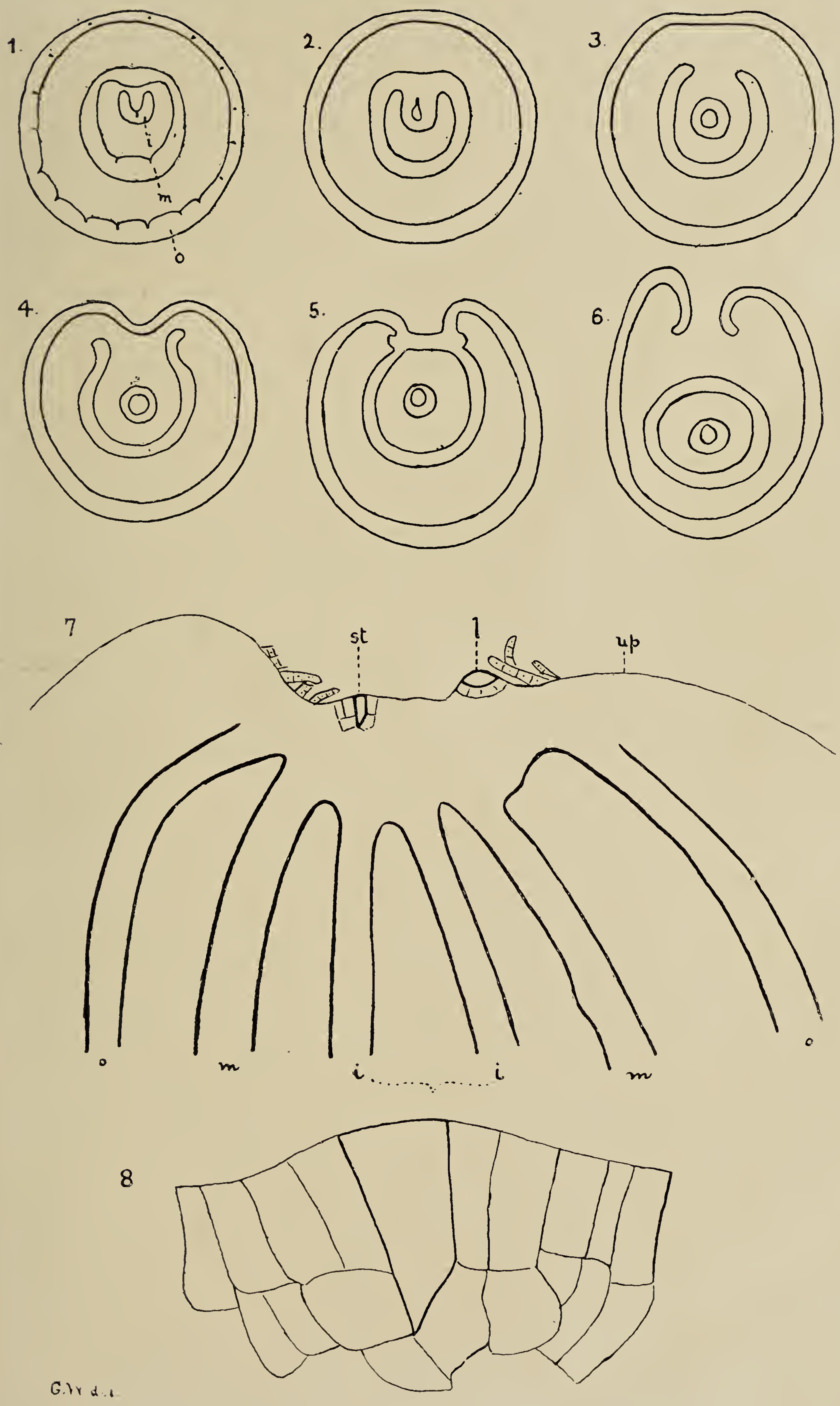
[1] H. Lohmann, "Die Coccolithophoridae, eine Monographie der Coccolithen bildenden Flagellaten, Archiv für Protistenkunde." Bd. I., 1902.



NOTES ON THE RHIZOME OF *MATONIA PECTINATA*.

NOTES ON
THE RHIZOME OF *MATONIA PECTINATA*, R.Br.

By Grace Wigglesworth.

[With Plate III.]

On examining the rhizome of *Matonia pectinata*, of which some preserved material was kindly sent to the Owens College by Mr. A. G. Tansley, I found the internal structure differed in some respects from that described by Mr. A. C. Seward,[1] and sufficiently, I think, to warrant a short description of the main points of difference. It should be stated at the outset that Mr. Tansley's material of *Matonia pectinata* was collected on Mount Ophir (Johore), while that examined by Mr. Seward came from Matang (Borneo).

A transverse section of the rhizome of Mr. Tansley's material, taken between two leaves, shows three concentric steles, separated from each other by several layers of parenchymatous cells forming part of the ground-tissue. The innermost stele encloses a central mass of similar parenchymatous cells, and is consequently distinctly siphonostelic, and not protostelic like the axial strand of Mr. Seward's *Matonia*. The outermost stele is narrower on the dorsal side, and the inner margin is crenulated on the ventral side. The middle stele has only two or three depressions on the inner margin of the ventral side, while the innermost stele has none or is only slightly depressed where the protoxylem group occurs.

The structure of the central stele is similar to that of the other two steles except that it has but one distinct protoxylem group instead of several. The protoxylem group lies on the inner side, and is ventral in position. The stele has a ring of wood vessels mixed with wood parenchyma, surrounded inside and outside by several layers of phloem-cells. The phloem is surrounded by a layer of parenchymatous cells (pericycle) and outside this is an endodermal layer of cells which often contain starch.

About half-an-inch in front of the leaf-insertion the stele is open, and U-shaped, so that the central mass of ground tissue is continuous with that lying without the central stele. At this point (see fig. 1) the middle stele is flattened dorsally and bent slightly inwards while the outermost stele remains annular. A little nearer the leaf the free ends of the open central siphonostele become united with the dorsal part of the middle stele (fig. 2), enclosing again a portion of the ground tissue in the central stele. The outer edge of the middle stele continues to bend inwards on the dorsal side, depressing the central siphonostele, which then separates from the middle siphonostele, in which a gap is now left (fig. 3); this gap widens, while the outermost stele first becomes flattened dorsally and then bends inwards between the two free ends of the middle stele, which have bent outwards as seen in fig. 4. Ultimately a connection is formed between the two steles. The two outer steles have now the form of a double horse-shoe connected by a bar across the narrow end of the inner one, which closes up the middle stele (fig. 5). The middle stele then becomes separated from the outer one, leaving the latter with a gap.

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[1] A. C. Seward. Structure and affinities of *Matonia pectinata*. Phil. Trans. 1899.

The incurved ends of the outer stele are prolonged upwards and continue into the vascular system of the leaf stalk (fig. 6).

Whilst the connection is taking place between the middle and outer steles the xylem of the central stele becomes interrupted on the dorsal side, but the endodermis and parenchymatous cells enclosed remain continuous.

Immediately behind the leaf insertion the three siphonosteles will be found concentrically one within the other and quite independent one of the other.

The main differences between the structure described above and that of Mr. Seward's material are at once apparent. The vascular system consists here of three complete siphonosteles.

It is not easy to compare at once the steles described above with those found by Mr. Seward. The outermost of the siphonosteles is much the same in both cases. It has numerous protoxylem groups (generally about eighteen) lying in the depressions, where the inner margin of the stele is crenulated. The middle siphonostele on the other hand, according to Mr. Seward's figure and description, has only one protoxylem group, whereas in the specimen described above it has numerous protoxylem groups and is also slightly crenulated. The innermost of the three siphonosteles, as stated above, has only one group of protoxylem, which would agree with that described by Mr. Seward for the second siphonostele, except that it occupies the ventral and not a dorsal position in the stele.

The occurrence in the same species of either a central siphonostele or a single axial strand, as in the specimen described by Mr. Seward, is of considerable interest, and bears out Mr. Seward's view that "the annular form of stele is not of great systematic importance." As Mr. Jeffrey[1] has shown in the case of *Pteris aquilina* the arrangement may vary even in the same stem. In *Pteris* a solid axial stele, with no ground tissue enclosed, was found up to the origin of the fourth or fifth leaf and then a core of ground tissue appeared inside the internal phloem.

Longitudinal sections through the apical region show that the steles arise from a common meristem, and that the innermost siphonostele is from the commencement a hollow tube (fig. 7). The steles appear emerging from the meristem as six bands of light-coloured tissue, separated from each other by the darker parenchymatous cells of the ground tissue, and gradually diverging into the thicker and more mature rhizome.

The connection of the three steles one with another, as described above, also differs from that described by Mr. Seward in the rhizome with the central axial stele. Comparing figs. 1-6 with Mr. Seward's fig. 5, it is seen that fig. 2, showing the connection between the innermost and middle steles in front of a node, corresponds with section 1 of Mr. Seward's figure, except that here there is a central mass of ground tissue present. But while section 2 of Mr. Seward's figure shows the middle stele open and the central stele still connected with it, in my specimen the innermost stele separates from the middle stele as soon as a gap occurs in the latter (fig. 3) and these two steles remain separated throughout the node. The opening of the middle stele takes place immediately after the fusion with the innermost stele, and it remains open until a fusion takes place with the outermost stele just before the leaf trace is given off (fig. 5), when it closes and remains, like the inner stele, closed throughout the node. The outermost stele does not open until the middle one is closed, so that two of the steles are never found open at the same time, as shown in section 3 of Mr. Seward's fig. 5.

The apical region is broad and lies in a depression, the under side of the rhizome projecting much more than the upper one (*up.* in fig. 7). It is protected by numerous multicellular hairs.

In a median longitudinal section (see fig. 7), a slight rounded protuberance at one side (*l*) with a large dome-shaped apical cell indicates a developing leaf. Mr. Seward has found a similar dome-shaped cell at the apex of the young pinnules.

The actual apex of the rhizome (*st*) is occupied by a single cell of larger size than the surrounding cells and appearing more or less triangular in longitudinal section (fig. 8). As I had only one apex at my disposal, and this had to be cut longitudinally, it is impossible to say whether this cell is three-sided or four-sided in surface view, but it seems most probable, as Mr. Seward suggests, that it is three-sided. On each side of the apical cell are narrow cells, cut off parallel to the inclined walls, and these have divided again by tangential walls to form the meristem from which the various tissues of the mature rhizome are formed.

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[1] E. C. Jeffrey. Memoirs of the Boston Society of Natural History, 1899.

Owens College, Manchester,
May 23*rd*, 1902.

EXPLANATION OF PLATE III.

Rhizome of *Matonia pectinata*.

Fig. 1. Transverse sections of the steles, about half-an-inch in front of a leaf insertion, showing the innermost stele open on the dorsal side, the middle stele flattened dorsally and bent slightly towards the gap in the innermost stele. The dots mark the protoxylem groups.

i=Innermost stele.
m=Middle stele.
o=Outermost stele.

Fig. 2. Transverse section slightly nearer the leaf insertion than Fig. 1, showing the innermost stele connected dorsally with the middle stele.

Fig. 3. Transverse section still nearer the leaf insertion. The innermost stele has separated from the middle stele and a gap is left in the latter. The outermost stele is flattened dorsally.

Fig 4. Transverse section behind that of Fig. 3. The innermost stele is annular, the two free ends of the middle stele have bent outwards and the outermost stele has bent down between them.

Fig. 5. Transverse section close to the leaf insertion, showing the innermost stele, still annular but narrower on the dorsal side. The middle and outermost steles have joined to form a double horse-shoe with a bar across.

Fig. 6. Transverse section at the leaf insertion. The innermost stele is unaltered, the middle stele is separated from the outermost and is now annular. The outermost stele has a gap, and the incurved ends have elongated to supply the young leaf.

Fig. 7. Longitudinal section through apical region showing apical cells of rhizome and leaf.

st=Apical cell of rhizome.
l=Apical cell of leaf.
up=Upper surface of rhizome.
i=Innermost stele.
m=Middle stele.
o=Outermost stele.

Fig. 8. Portion of Fig. 7, more highly magnified.

CORRESPONDENCE.

THE HEURISTIC METHOD IN THE TRAINING OF ELEMENTARY TEACHERS.

To the Editor of the "NEW PHYTOLOGIST."

SIR,

Your readers will perhaps be interested to hear of an experiment in botanical teaching suggested to me by Mr. Seward's paper in the first number of the "NEW PHYTOLOGIST."

The experiment was made in my "Elementary Biology" Class of fourteen women students, in training at the Darlington Training College as teachers in Elementary Schools. Our time was limited to two hours a week for one year, and in these two hours the students had to be introduced to the principles of Plant and Animal Life, for with one exception none of them had any previous knowledge of Botany or Zoology (perhaps not altogether a disadvantage !).

When I read Mr. Seward's paper, it seemed to me that though few of us teachers have such a class as his at Cambridge, yet we might easily adapt his method to suit the needs of our own particular students. For instance, my students had not the time, material, or ability for actual research work, but—set to work on simple problems—they might find out a great deal for themselves, getting useful experience and training by the way, even if what they discovered was quite familiar to the big botanical world outside.

Early in March, I divided the class into three sets, and to each set gave different work to do. For the benefit of other teachers I will describe the work rather fully, trusting that research students will not scorn our simple problems or forget our two hours' limit !

Set I. were to work on Trees and their buds. They were to find out and note the times of opening of different tree buds, to investigate the length of shoot derived from a single bud in different trees, etc., also to hunt for any possible relations between the branching of a tree and the veining of its leaves, and for any record of past seasons in the bark or wood of a tree.

Set II. were to work on Seedlings,—cultivating various kinds in sawdust, with a view to tracing what became of the various parts, noting especially the history of the seed-leaves, the way in which they were withdrawn from the seed-coat, and the differences between these and the foliage leaves, etc.

Set III. were to make out the relation of Rain to the plant-world; to note how plants made most use of it; to discover in what ways it might prove harmful, and how the danger was guarded against; particularly to notice how the position in which flowers and other parts were held was affected.

The students themselves chose which set they would work in, and the work was done quite voluntarily. The members of a set worked separately for the most part, coming to head-quarters in practical difficulties. Some of the facts they could have got from books, but I discouraged references to these as destroying any originality in the work.

At the beginning of June almost every student gave in a written account, with illustrative sketches of the observations she had herself made, and from these I chose three representatives who gave informal accounts of their observations for the benefit of the rest at the last class of the Session. These accounts occupied about fifteen minutes each, and were supplemented by observations of others who had worked in the same set. The show of seedlings in boxes was really exciting. Many kinds were tried and the following were found very useful :—beans, peas, lupins, vegetable marrows, tropæolums, mustard, cress, buckwheat and maize. One bean-seedling grew to twenty-seven inches above the sawdust, and showed flowers after about seven weeks' growth. Great interest was aroused by the varying length of shoot from a single bud, the connections between branching and veining, and the position and movements of flowers as protection against rain.

The greatest value of this method seems to me to lie in the actual experience of practical difficulties (even of growing seedlings, or measuring tree-shoots) which the students gain, and which I am sure cannot fail to be useful to them in their own teaching. It also arouses keen interest in plants as living things, and gives greater power of solving the many smaller problems of plant-life which are continually cropping up in any Botany class. It also provides training in close observation, and clear expression.

A similar method (as indicated in a paper in your June number) would be very valuable in a School. Indeed, in so far as my students were beginners, the *work* given them approximated to School work in character, although, of course, the treatment of the *worker* must be rather different in School and College. But even though my students were grown-up, the two hours a week allowed of very little Greek! Indeed we only troubled ourselves with technical terms when they were really wanted. For I have always thought that Botany is voted "dry" only because the learning of an entirely new language is too often the introduction to the subject. When the beginner is presented first of all with the actual plants, and is led to see the relations between form and function, etc., he can only be fascinated. The necessary terms can then be brought in as the need for them is felt, the result being a far more real, if less pretentious, knowledge of the plant-world.

Although many improvements suggest themselves in our experiment of this year, we—class and teacher—have found it so useful and interesting that we shall have no hesitation in making fresh experiments on the same lines next Session.

With thanks to the "NEW PHYTOLOGIST" for the original suggestion, and hoping to hear of the experiences of others who have acted upon it,

I am, Sir,
Yours, etc.,
EMMA E. HART.

Darlington,
July 1st, 1902.

SYSTEMATIC BOTANY FOR CHILDREN.

To the Editor of the "NEW PHYTOLOGIST."

DEAR SIR,

A writer in the June number of the "NEW PHYTOLOGIST" makes some useful suggestions with regard to the teaching of Botany to children. May I draw attention to one phase of the subject, the systematic, which, to say the least, is not encouraged in the article to which I refer. We know that it has been much abused in the past, but that is no reason why it should not prove helpful in the future. It is quite possible to learn something of the relationships of plants to each other, as well as to insects and other factors in their environment, without the burden of numerous technical terms.

Take for instance the Rose family (you need not call it Rosaceae)—a very short walk will enable you to find quite a number of members which have certain points in common, and certain special characteristics, both easily observed. For instance at present you can find wild roses with the young fruits sunk in a cup, the Strawberry and Potentilla with them raised on a central cushion, which in one case becomes fleshy, in the other remains dry; then if you like you can go on to the less obscure case as shown in the ripening apples where the young fruits have grown to the flower-cup. Then there are Blackberry, Herb-Bennet, Burnet, the latter flower small but full of possibilities, both family and biologic,—its Potentilla-like leaves give a clue to the family, and if a lens is available there is the flower-cup comparable with that in the rose, but dry instead of fleshy and protecting a limited not an indefinite number of fruits. Throughout you find the persistent sepals, the numerous stamens, and (except in Apple) the free fruits, while the leaves though showing great variety are all stipulate, this character sometimes even invading the flower. Compare the Buttercup with these; the stamens and carpels are numerous but the sepals fall easily, the leaves have no stipules, while the convex axis affords a striking contrast to the flower-cup in the rose. If Clematis is handy, note the same type of flower, but without petals: the University teacher may some day be delighted not to have to expatiate on the absurdity of a group Apetalae based merely on absence of petals.

Earlier in the year there are the trees with their catkins, a mark of kinship, and the stipules transient structures merely for bud-protection.

Caryophyllaceae again (call it Stitchwort and Campion family), what obvious characters the members have in common, falling at the same time into two sets, the open-flowered (you need not call it Alsineae) and the tubular. And then you can bring in the insects.

These are a few examples taken at random, but the store is inexhaustible, for as you go on you find you can go deeper. A few terms are necessary, but sepals, petals and stamens are not very dreadful, and stipules no more appalling than cotyledons. A wise teacher will see when the little brains are beginning to fog over, and stop. And of course he will not dwell on exceptions, which by the way are not by any means peculiar to systematic work. It is possible to cavil even at the simple statement that "a seed does not germinate unless it is damp and warm"—what do you mean by damp? what do you mean by warm?—except when the ground is hard with frost, the ditch-sides are green with seedlings of cleavers, and the driest, dirtiest of road-sides will supply some specimens.

Without depreciating other methods I think, Sir, that I have illustrated one, which is not over-burdened with technical terms, requires no apparatus, and has the great advantage of systematising the facts which are observed.

Believe me,
Yours truly,
A. B. Rendle.

British Museum (Nat. Hist.),
July 3rd, 1902.

A REVISION OF THE CLASSIFICATION OF THE GREEN ALGÆ

BY
F. F. Blackman,
University Lecturer in Botany, Cambridge.
AND
A. G. Tansley,
Assistant Professor of Botany, University College, London.

(*continued from page* 144.)

Fam. VIII. Coleochaetaceae.

Thallus generally epiphytic, consisting of *an attachment-plate* which is a more or less concrescent branch-system (sometimes pseudoparenchymatous) *with or without erect free vegetative branches. Some cells* of the attachment-plate or of the erect branches *bear* characteristic stout *stiff sheathed "setae" with a definite lumen.* Cells, cylindrical or polygonal by compression, with a single large parietal chloroplast and one pyrenoid.

Reproduction by bi-flagellate zoospores and *by oogamy.* Oogonium terminal, flask-shaped, opening by a long neck and containing a single spherical egg with a large chloroplast. Antherozoids oval, bi-flagellate, devoid of chlorophyll. After fertilisation the oogonium becomes invested with a single-layered "cortex" of concrescent thallus-branches which ruptures on germination.

The spherical oospore rests for a long time, still retaining its chloroplast and then germinates by dividing into a radiating cluster of about thirty cells. In each of these resulting thin-walled cells there develops a single bi-flagellate zoospore which escapes by rupture of the cell-wall. The zoospores after swarming grow at once into new plants.

Genus.

Coleochaete. Brébisson, 1844.

Thallus a tuft of straggling branches, or a cushion of concrescent branches, or a flat monostromatic plate. The zoospores and the antherozoids arise singly in any of the cells of the thallus or only in the end cells of branches; eye-spot absent.

[This family is separated from the three previous families by the occurrence of oogamy and the indirect germination of the oospore. The range of forms of thallus-reduction is very wide for a single genus but they are strictly comparable with different types of the Chaetophoraceae. The presence of sheathed setae suggests a common origin for this family and the previous one and the germination of the zoospores of some species of *Coleochaete* recalls the mode of growth of *Chaetosphaeridium*]

Fam. IX. CHROOLEPIDACEAE.

Thallus hydrophytic or aerial, consisting of a more or less *concrescent branch-system, without hairs, setae, or filar processes,* and usually attached by a wide base.

Chloroplast a single parietal plate, usually devoid of pyrenoid.

Reproduction by *zoospores* (typically bi-flagellate), *arising in large numbers in a zoosporangium which* usually *differs* distinctly in size or shape *from the vegetative cells.* Isoplanogametes have also been observed in some cases.

[This family stands opposed to the four previous families collectively by having no tendency to form hairs, setae, or filar processes, but like those families, it is apparently made up of reduction-series of forms derived from freely branched types. These hairless series have probably a common origin with the Chaetophoraceae; the lower members, however, are at present imperfectly known.]

Sub-Family I.

Gongrosireae. Hydrophytic forms devoid of haematochrom.

Genera.

*Thallus erect, freely branched with a small basal attachment.

1. *Microthamnion.* Nägeli, 1849.

Thallus a di- or trichotomous branch-system, epiphytic by a basal cell. Branches elongated and quite free from one another. Cells cylindrical, long, with a single parietal chloroplast and no pyrenoid. Zoosporangia arise by swelling of the terminal cells of the branches, but the free zoospores have not been observed. Gametes unknown.

2. *Chlorotylium.* Kützing, 1843.

Thallus a hemispherical cluster of branches, imbedded in mucilage and often calcified. Swollen cells occur at similar positions along all the branches, giving rise to a concentric arrangement. Bi-flagellate and quadri-flagellate swarmers of unknown function occur, also akinetes and palmelloid-states.

**Thallus a creeping basal branch–system, from which erect branches arise.

3. *Acroblaste.* Reinsch, 1879.

Thallus a richly branched basal plate with erect simple or compound branches. Chloroplast large, single, no pyrenoid.

Reproduction by numerous zoospores arising in swollen terminal zoosporangia.

4. *Leptosira.* Borzi, 1883.

Thallus a clustered, dichotomous branch-system. Cells barrel-shaped, with a single chloroplast and no pyrenoid.

Reproduction by bi-flagellate zoospores and isoplanogametes. Any thallus-cell may develop to a swollen zoosporangium or gametangium.

5. *Gongrosira.* Kützing, 1845.

Thallus flat or cushion-shaped, often incrusted, consisting of a clustered irregular branch–system. Chloroplast typically a single parietal plate, but often fragmented; 1-3 pyrenoids occur.

Reproduction by bi-flagellate zoospores, occurring in large numbers in usually terminal swollen zoosporangia. Isoplanogametes observed.

6. *Foreliella.* Chodat, 1898.

Thallus a straggling branch-system or sometimes pseudoparenchymatous, perforating fresh-water shells. Zoosporangia and swollen akinetes arise on the superficial erect branches. Zoospores not observed.

***Thallus a creeping branch-system, devoid of erect branches.

7. *Trichophilus.* Weber v. Bosse, 1887.

Thallus an irregular branch-system, all in one plane, and sometimes concrescent to form a disc. Cells thick-walled with several small chloroplasts and no pyrenoid. Zoosporangia intercalary, swollen, and containing swarmers of an uncertain nature.

8. *Gloeoplax.* Schmidle, 1899.

Thallus a flat mucilaginous matrix in which are embedded a number of short branch segments, any cell of which may swell up to form a zoosporangium. Zoospores bi-flagellate and germinating to re-form this palmelloid mucilaginous mass.

[The affinities of this alga are obscure, and possibly the whole life-history is not yet known.]

9. *Dermatophyton.* Peter, 1886.

Thallus irregularly discoid, growing in fissures in the shell of a fresh-water tortoise. The central part of the disc becomes many-layered by secondary divisions. Zoosporangia peripheral, flask-shaped, producing many zoospores.

[The true systematic position of this alga is uncertain. Schmidle has found it to be multinucleate and proposes to unite it, on morphological grounds, with *Ulvella* (in the type-species of which, however, the number of nuclei in the cell is still unknown) assigning both forms to the Cladophoraceae.]

Sub-Family II.

Chroolepideae. Aerial forms; haematochrom abundant in the vegetative cells.

Genera.

*Thallus freely branched, partly creeping and partly erect.

10. *Trentepohlia.* Martius, 1817.

Thallus an irregular or dichotomous branch-system of very varied habit. Cells usually short with several angular chloroplasts and no pyrenoids. Reproduction by biflagellate zoospores or isogametes which arise in large numbers in swollen terminal thallus-cells, often of very specialised form.

**Thallus epiphyllous, a pseudo-parenchymatous disc produced by the concrescence of a branch-system and with only short erect branches.

11. *Phycopeltis.* Millardet, 1870.

Thallus a rounded disc epiphyllous on aerial evergreen leaves, and devoid of rhizoid-branches. Chloroplasts several in the cell and without pyrenoids. Reproduction by biflagellate zoospores, devoid of eye-spot, arising in large numbers in the zoosporangia.

12. *Cephaleuros.* Kunze, 1828.

Thallus a lobed disc of one layer of cells bearing much-branched unicellular rhizoids below, and sometimes also tapering erect branches. The thallus spreads below the cuticle of thick leaves and is partly parasitic.

Chloroplasts small, discoid, several in the cell and without pyrenoids.

Zoosporangia large, swollen, terminal, producing a number of bi-flagellate zoospores.

Class II.—STEPHANOKONTAE.

Motile reproductive cells with a crown of cilia round the clear anterior end.

[The only known forms of this class are filamentous.]

Family Œdogoniaceae.

Thallus fixed, consisting of simple or branched filaments uninucleate cells. *Cell division accompanied by the intercalation of a new piece of membrane to form the side wall of the upper daughter-cell*, giving rise to the characteristic "capping" of the upper cell.

Chromatophore consisting *of parietal, anastomosing longitudinal bands, which may fuse to form a continuous parietal layer.* Pyrenoids one or more.

Reproduction by Stephanokontan zoospores, each produced singly from a vegetative cell, and by oogamy.

Genera.

1. *Œdogonium.* Link, 1820.

Thallus an unbranched filament, fixed by a special basal cell. All cells, except the basal, capable of division. End-cell of the filament sometimes becoming a hair-cell.

Reproduction by zoospores and by oogamy, the antheridia, producing Stephanokontan antherozoids, either formed directly from vegetative cells, or in minute few-celled plants (*dwarf males*), which arise from special Stephanokontan swarmers (*androspores*), themselves produced from vegetative cells. The round or elongated oogonia develop from newly formed vegetative cells by swelling, contain a single egg-cell and open by a lateral pore or by a lid. Germination of zygote gives rise to zoospores, each of which forms a new vegetative plant.

2. *Bulbochæte.* Agardh, 1817.

Thallus a fixed, repeatedly branched filament, each branch terminating in a long sheathed bulbous hair-cell. The basal cell of each branch is alone capable of adding cells to its branch by division; each newly cut-off segment functions in its turn as the basal cell of a new branch, and grows out to form first the terminal hair-cell and then the vegetative cells. Cell division and reproduction as in *Œdogonium.*

3. *Œdocladium.* Stahl, 1891.

Thallus terrestrial, consisting of a creeping filament bearing aerial assimilating, and subterranean colourless absorptive branches ("rhizoids"). Cell-division almost confined to the apical cells of the branches. Intercalation of new membrane at cell-division as in *Œdogonium.*

Reproduction by Stephanokontan zoospores, and by uni- or multicellular bulbils (specialised akinetes) borne as branches of the subterranean "rhizoids." Gametes unknown.

Class III.—CONJUGATAE (AKONTAE).

Plant-body consisting of a single cell or of an unbranched filament of cells.

Chromatophores various, one or more in the cell, but *always symmetrically arranged with reference to an axis. Pyrenoids always present.* Starch always formed. Nucleus usually accurately central in the cell.

Reproduction by conjugation of non-ciliate gametes (*aplanogametes*), *each derived from the whole* (*or nearly the whole*) *body of a vegetative cell. Gametes never escaping from investment of cell-membrane.*

Conjugation may occur between the whole bodies of distinct individuals (unicellular forms), or between the cells belonging to distinct individuals; or it may occur between the adjacent cells of a filament. The zygote in the former case may be produced isogamously in the *conjugation-canal* (an open tube formed between the two conjugating cells), or anisogamously in the cavity of the mother-cell of one of the gametes. Reproduction also by aplanospores. *Zoospores entirely absent.* All fresh-water forms.

[The affinities of this very isolated and sharply-characterised group are obscure. It may possibly have been derived from a primitive motile green form. *Chlamydomonas Braunii* furnishes the closest analogy among the Green Algæ with the peculiar method of conjugation.]

[The classification here adopted was suggested by Palla, *Ber. d. deutschen Bot. Ges.*, 1894. It is largely based on the chromatophores, since a comparative consideration of the group shows that the nature of these is a more constant character than the minor differences in the method of conjugation usually employed to separate the families.]

Series I. **Desmidioideae.**

Plant-body unicellular, free or united in unbranched filaments; *cells large*, of various shapes, but *usually symmetrical about three planes at right angles to one another.* Cell often constricted in one of the planes of symmetry (*equatorial plane*) often symmetrically lobed, and frequently with a sculptured wall. Cell-wall usually penetrated by protoplasmic threads, which secrete mucilage outside the wall, thus forming a mucilaginous sheath round the cell.

Chromatophores usually two, one on each side of the equatorial plane, most frequently consisting of axile plates with symmetrically disposed ridges. Pyrenoids large, symmetrically arranged. Nucleus accurately central.

Multiplication by bi-partition in the equatorial plane, the inner halves of the two daughter cell membranes being formed by the intercalation of new pieces between the two halves of the mother-cell, which form the outer halves of the two daughter-cells.

Zygote formed in the conjugation-canal or in the cavity of one of the conjugating cells.

Practically all fresh water forms, avoiding calcareous water.

(*To be continued.*)

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TOWARDS AN IDEAL BOTANICAL CURRICULUM.

Part II.

THE ELEMENTARY UNIVERSITY COURSE.

IN any attempt to deal with the details of the organization of University education in science, account must be taken of those newer theories of teaching, which would substitute the discovery of the facts at first-hand by the students for the old instruction by set lectures followed by illustrative practical work. That there is much to be said on general educational grounds for this abandonment of the " method of instruction " for the " method of discovery " is at once obvious; but there are certainly serious dangers in the newer method, and it may fairly be doubted whether we are ready for an immediate and wholesale change such as is advocated by the more extreme of the reformers. It is not intended to discuss here the pros and cons of this question, but it may be suggested that the ideal scientific curriculum will ultimately be found in a judicious combination of the two methods. Our present need is to keep a perfectly open mind, to try as many quiet experiments as possible, and constantly to revise our schemes in the light of experience.

All that is intended in the present articles is to put together some ideas on the organization of a University curriculum in botany. Most of what is said will apply as well to a course based on the " heuristic " method as to one which follows more traditional lines.

First a word on the organization of a University botanical department in regard to elementary work. The chief Professor, with supreme control of the department, should, we think, always be responsible for conducting the general elementary course. That duty is, of course, a traditional one, and we believe the maintenance of the tradition is of great importance. The delegation of elementary teaching to younger and less experienced men, a change now being advocated in certain quarters, is fraught with grave dangers. Younger men are far more likely to despise elementary teaching than older ones, and they cannot in any case have acquired that matured and balanced view of the subject which is absolutely essential to really good general teaching. It is fatal also for the chief Professor to get out of touch with his elementary students, the raw material out of which future botanists must be made. It should be his care to know them as far as possible individually, to encourage and stimulate their interest and enthusiasm, to make them feel that they belong to a department with single aims and a single chief. Except in the case of enormous classes these are not at all impossible tasks if the Professor once faces them and knows how to use his demonstrators as aides. Of course it is not meant that the Professor should spend his time in demonstrating the structure of *Spirogyra* in the laboratory. That can safely be left to his demonstrators. But he should be about the laboratory for a certain time during each elementary practical class, looking through a microscope here, talking to a student there, and generally making his presence felt. The objection may be made that all this involves great waste of the Professor's valuable time. The answer is that it is work which must be done if the department is to be a success, and it is work that can best be done by a man of matured experience who has the prestige attaching to the headship of a department. In a word it is work which the Professor should regard as one of his chief concerns. The Professor who remarked that it was "not his business to make chemists but to make chemistry" had, as head of a teaching department, mistaken his vocation.

It is essential that the Professor should have the qualities of sympathy and imagination, that he may undertand his students and their difficulties, and of enthusiasm, that he may gain a real influence with them. He should devote at least half of his time and energy to the general elementary course. We may assume that this should occupy a full working year, the class meeting three days a week for three or four hours, and should aim at covering the general principles, outlines and methods of modern botany. Whether it should follow traditional lines, or should be modelled upon the lines which Prof. Miall has adopted with such striking success in his elementary class at the Yorkshire College, Leeds, is a question we cannot enter upon here. But in any case, too much attention can hardly be given to making the course vital and stimulating. It is by far the most important part of the student's curriculum. The effect it has on his mind may determine not only the particular course of his future career, but the whole mental effect of his scientific training. His mind may never recover from the deadening effect of dull and pedantic elementary teaching, or if it does recover, it will be much later, and at the cost of a terrible waste of time and mental energy.

With the actual material of the course, we need not deal. It must be largely the same in all cases, but different teachers will naturally modify it in accordance with their own idiosyncracies. It need hardly be said that the main thing is to keep the living plant constantly before the mind of the student; the plant as a being, with its immediate vital needs on the one hand, and its long evolutionary history on the other—a history worked out by means of constant adjustments of its structure and functions to these needs in the changing conditions of life.

It should be insisted that the student entering upon his botanical work should understand the elements of chemistry and physics. In an ideally organized University the student of science should go through elementary courses of chemistry and physics in his first year after matriculation, and of two other subjects, of which botany may be one, in his second. He ought not to be called upon to give his attention to more than two subjects during the same year. In this way ample time would be left for more or less independent work in the laboratory or field work, which the keener students should be encouraged to pursue, and for which they should be given ample facilities. This work should not be at all formal: the student should be allowed to do just what he likes, and any suggestions or help that he may want should be forthcoming from his demonstrators. Under the present system, in which far too much work is crowded into a year, there is always a certain number of students who want to go further into various topics which arise; but it is usually impossible, owing to the pressure of other subjects. On the other hand, students who have no desire for this supplementary work should not be worried to do it. They will be far better employed in games or other recreation.

The reading of text-books is, we believe, on the whole undesirable for properly taught elementary students. Such information as a student desires over and above what he is taught or can find out from the plants themselves should be given by his demonstrator.

Conversation on points of interest should be encouraged in every way; it tends to the creation of a stimulating "atmosphere." But if reading seems desirable, the Professor or demonstrator can of course recommend what they think fit. We have not, however, found that elementary students are particularly anxious to read, except from the point of view of examination-cramming; and the examinations should be arranged so that such reading is of little use. A student is much better employed in worrying out a practical point in the laboratory, or in talking over a theoretical point with his demonstrator than in reading someone else's descriptions, or "getting up" a probably sketchy account of a topic in an elementary text-book. A demonstrator who knows his business is necessarily better than any elementary text-book. Standard books of reference of the type of De Bary's "Comparitive Anatomy," and Pfeffer's "Physiology" should of course be immediately accessible in the laboratory. The keener students will thus naturally tend to spend most of their time available for botany in the laboratory, and this in itself is all to the good. A demonstrator should always be accessible during the hours the laboratory is open. He should by no means consider his duties ended when the regular class is over. This, of course, involves the existence of at least two demonstrators with adequate stipends, in order that they may have time to themselves.

We consider that even in the case of an elementary class, by far the best examiner is the teacher, and hence the examination at the end of the year ought to be conducted by the Professor. There is clearly no objection to an independent examiner being associated with the Professor, if this is thought desirable. But even if the examination is an outside one, so far as departmental teaching is concerned, students who have been encouraged to look and think for themselves instead af depending on a more or less mechanical reproduction of the contents of text-books, will not find their training fail them in the examination-room.

Probably the greatest fault which still exists in science examinations is the tendency to set questions, the answers to which depend mainly on the mere exercise of memory. What is wanted is a test of the firm grasp of fundamental conceptions and principles, and of the power of "tackling" an unknown object, *i.e.* of interpreting the unfamiliar in the light of thorough knowledge of the familiar. The faults n training indicated are constantly being revealed at public examinations in botany, where candidates frequently give careful text-book descriptions of what *ought* to be seen in objects given them to describe, instead of finding out what *can* be seen by actual examination.

We are inclined to think that a student who has been through elementary courses in four scientific subjects, and attained a high standard in the final examinations, might well be granted an ordiary science degree without more ado. The present pass degree examinations at the University of London have the double fault of putting too great a strain on the memory by covering too wide a field of detailed knowledge, and at the same time of allowing the candidate to pass on a ridiculously low percentage of marks—a direct incentive at once to cramming and to slovenly work. If the field were restricted to what would naturally be taught in four courses such as we have indicated, and the candidates examined by their teachers at the end of each course, a high pass standard being insisted upon, a certain breadth of training would be secured, and excessive mental strain, with its educationally vicious results, entirely avoided.

With advanced botanical teaching and its relation to research we will deal in another article.

THE MEETING OF THE BRITISH ASSOCIATION.

BY general consent the recent meeting of the British Association at Belfast, was not marked by features of very striking interest, and Section K shared to some extent in the general though the average of excellence was well maintained, none of mediocrity. There was a plentiful supply of papers, but these announced discoveries of very unusual interest. The entire absence of distinguished foreign botanists also robbed the meeting of an attraction which members of the section have rather come to expect. The local arrangements were, however, very good, and the local Secretary, the Rev. C. H. Waddell, did everything possible for the comfort and convenience of members.

The actual meetings of the Section passed off very smoothly, without any hitch, and were singularly, perhaps undesirably, free from any trace of animated discussion. The arrangement of papers as announced in the "Journal" was very closely adhered to. At the suggestion of the President the experiment of meeting only in the morning, was tried, and was generally voted a success. A perfectly free afternoon gives a welcome respite from the rather tiring business of listening to miscellaneous papers.

THE PAPERS.

We propose to notice only a few of the more important papers that were read.

The President's Address dealt mainly with important present-day problems of plant-physiology, particularly metabolic problems. The mechanism of carbon assimilation, the question of the possibility of the monoxide replacing the dioxide in the process, the various stages in the subsequent synthesis of sugars and of proteids, were all touched upon, as well as the relation of the alcohols to protoplasm and the interesting question of the physiological independence of the endosperm of seeds, as shewn by the renewed metabolic activity of its cells apart from the influence of ferments excreted by the embryo. Electrical phenomena in plant-tissues were also dealt with, and the suggestion made that they may be of much greater importance in relation to various metabolic processes than has hitherto been supposed.

Professor J. C. Bose gave an attractive demonstration of his experiments on the electrical response of plant-tissues to mechanical stimulation. By means of a galvanometer connected with the two ends of a piece of tissue and reflecting a spot of light on to a screen the audience was able to follow the results of the experiments with ease. Professor Bose's general results show a striking similarity with similar phenomena in animal nerves.

Dr. Allan Macfadyen read an interesting account of researches by himself and Mr. Sydney Rowland on the Suspension of Life at Low Temperatures. Various bacteria were exposed to the temperature of liquid hydrogen (about 252°C.) for ten hours, and to the temperature of liquid air for six months, and in no case was any impairment of vitality obtained. The authors point out that intra-cellular metabolism must cease entirely at such temperatures and call attention to the difficulty of forming a conception of the actual state in which living matter exists in this condition, which is neither life nor death. In the discussion which followed, Dr. Morris Travers suggested from the analogy of the behaviour of certain chemical substances, that a *slow* cooling through intermediate temperatures might result in the death of the protoplasm.

Dr. H. H. Dixon gave an account of some experiments on the Resistance of Seeds to High Temperatures. He found that seeds thoroughly dessicated over sulphuric acid could withstand temperatures varying according to the species from 90°C. to 120°C. for at least an hour.

Miss Matthaei read an important paper on the Effect of Temperature on Carbon Dioxide Assimilation. The generally accepted view has long been that this function increases with rise of temperature from 0°C to about 15°C. and then remains unaffected by further rise, giving a curve which shews a sharp preliminary ascent and then a long, approximately flat top, as figured in Pfeffer's "Physiology of Plants." Such a curve, though hitherto unquestioned, has no parallel in plant-physiology, and no clear rationale. Miss Matthaei's researches prove that the true curve shews a steady continuous rise; and thus assimilation is brought into line with other vital functions. The "flat top" is shewn to be due to experiments with insufficient illumination, the assimilation having been naturally unable to increase beyond the limit imposed by the inadequate amount ot radiant energy reaching the leaf. Miss Matthaei's researches were carried out in Mr. F. F. Blackman's laboratory at Cambridge.

Of morphological papers one of the most interesting was Mr. J. C. Willis', "On the Dorsiventrality ot the Podostemaceæ, with reference to Current Views on Evolution." The author shewed that in this curious order—upon which he has extensive memoirs in preparation—a series of types can be traced shewing a gradual increase in dorsiventrality at first in the vegetative body alone, and then in the flower, finally extending to the embryo itself. This dorsiventrality of the flower is clearly not an adaptation to insect-visits, as is so often the case, since the more zygomorphic the flowers the more do they shew anemophily or autogamy. The most obvious view is that the increasing dorsiventrality of the plant-body has gradually forced itself upon the flower, which is more and more profoundly affected, without gaining any obvious advantage in the struggle for existence. This character of dorsiventrality in the flower and fruit is largely used in classifying the Podostemaceæ into sub-orders and genera, but it is clear that if there is a progressive tendency to dorsiventrality in the plants belonging to this family, it may have taken effect in a similar manner and produced similar results in series of forms living in different parts of the world. Hence it seems likely that sub-orders, genera, and species may be polyphyletic, owing to this parallel or convergent evolution. Such a conclusion, of course, considerably affects our views on the relation of the geographical distribution of the family to its evolution.

Professor F. W. Oliver gave a preliminary account of an investigation which is being made by Miss Edith Chick and himself into the morphology of the Coniferous genus, *Torreya.* It seems likely that *Torreya*, of which practically nothing is hitherto known, will prove not less interesting than *Ginkgo*, as a rather isolated and ancient genus of Gymnosperms. Professor Oliver's account related principally to the seed, which is a complicated structure shewing a clear affinity with some of the Palæozoic Gymnospermous seeds. The view was put forward that while the apex of the seed is an ancient structure, the lower part has been more recently intercalated. Mesarch structure has been found in the cotyledon petiole, and a very clear transition can be traced between the centripetal xylem and the abundant transfusion-tissue. The mesarchy does not, however, extend into the hypocotyl as it does in *Ginkgo.*

Of the papers on fossil botany, two important contributions were made by Miss Benson. In one of these the seed-like fructification of *Miadesmia membranacea*, which has already been described and figured by her in the March number of this journal (p. 58) was dealt with. It is a curious fact that while there is a very strong probability of the modern seed-plants having been derived from an old Fern-stock, the two examples of "incipient seeds" at present discovered—*Lepidocarpon* and *Miadesmia*—should both belong to the Lycopodineous phylum. In the other paper Miss Benson described a group of sporangia probably belonging to what is known as the "*Calymmatotheca*-type," shewing a thick wall of several layers of cells and some large tracheids. The close association of these sporangia with petioles of *Lyginodendron* leads to the hypothesis that they really belong to that plant. If this should prove to be the case, it will be the first recorded instance of a Cycado-filicinean fructification The structure of the sporangia is of special interest in connexion with Professor Oliver's form, provisionally named *Tracheotheca*, also described in the March number of this journal, (p. 60). Possibly this type of sporangium with a vascular wall was in Palæozoic times widely distributed among plants of Filicinean affinity. If it is really a forerunner of the seed of Phanerogams, the discovery of the intermediate types will be awaited with great interest.

Professor Oliver delivered the "semi-popular" lecture on "Ancient and Modern Seeds," bringing together the facts known as to the conditions of evolution of the seed. The latter part of the lecture was devoted to a consideration of the complicated seeds of the "Cycadean type" which shew numerous variations in the arrangement of their vascular supply. An attempt was made to indicate the probable course of evolution of these seeds, which is thought to be largely determined by the necessities of water-supply.

Cytology was represented only by two papers read by Mr. Harold Wager, one giving an account of his admirable work on the Nucleus of the Cyanophyceæ, and the other relating to the Function of the Nucleolus. In the former he summed up the points in which the "central body" of the Cyanophyceous cell resembles the nucleus of an ordinary plant cell. From this it appears that the former may very fairly be called a nucleus, though Mr. Wager hesitated to do so. It is, of course, a nucleus of very primitive type which has not acquired some of the distinctive characters of the ordinary nucleus. Mr. Wager's view of the function of the nucleolus is that it feeds the chromatin. He has obtained preparations shewing the nucleolus in actual organic connexion with the chromatin network. He does not, however, deny that it may also help to form the achromatic spindle, as is held by Stasburger and his school.

Mr. Lloyd Praeger, the well-known authority on the distribution of Irish Plants and author of the recently published "Irish Topographical Botany," read a paper on "The Composition of the Flora of the North-East of Ireland," in which he gave an excellent account of the occurrence of the various geographically determined "types" of Irish plants in Counties Down and Antrim. The paper was illustrated by Mr. Praeger's excellent distributional maps.

EXCURSIONS.

On Friday, Mr McKim, the curator of the Botanic Park, shewed several members of the section round the "Fernery" where tree-ferns and bananas with numerous other tropical plants are arranged with great taste and growing with quite exceptional luxuriance. On the testimony of more than one botanist, familiar with the vegetation of the moist equatorial region, the scene was "more tropical than the tropics."

Several botanists went to Newcastle, Co. Down, with the regular Association Saturday Excursion, but instead of following out the rest of the programme, on arriving at the station they drove straight to Castlewellan, an introduction having been obtained to Lord Annesley, who very kindly took the party round his garden. The very fine collection of trees and shrubs was much admired. Several Conifers, such as *Fitzroya patagonica*, *Dacrydium*, etc., which rarely cone in this country, were in fruit. A great feature of the garden was the lovely *Tropæolum speciosum*, which was climbing over the trees in the freest way, thoroughly at home.

On Tuesday afternoon the members of the section, under the guidance of several local botanists, among whom was Mr. S. A. Stewart, curator of the Belfast Museum and author of the "Flora of N.E. Ireland," visited Colin Glen, about an hour's drive from the city, by kind permission of the proprietor, Mr. McCance, and several interesting plants were gathered. The locality is particularly rich and singularly beautiful. The members were entertained to tea by Mr. and Mrs. George Kidd, who earned the warm gratitude of their guests by their delightful hospitality, a gratitude which was suitably expressed in a little speech by the President of the Section.

OBSERVATIONS ON THE PYROCYSTEÆ,

By V. H. Blackman, M.A.

Assistant, Department of Botany, British Museum.

With Plate IV.

THE family of the Pyrocysteæ comprises but a single genus. *Pyrocystis*, a name aptly given, during the voyage of the "Challenger," to two unicellular free floating organisms on account of their strong luminous power. One of the organisms being similar in form and luminosity to the interesting member of the Cystoflagellata, Noctiluca, received the name of *P. pseudo-noctiluca*, while the other, owing to its shape, was called *P. fusiformis*. They were first figured and briefly mentioned by John Murray (6)[1] in 1876, but the names appear under the authority of Wyville Thomson. These two forms are often found in abundance in the surface waters of most tropical and sub-tropical regions, but they are usually confined to the open sea; both are of large size, *P. pseudonoctiluca* reaching a size of 0.5 mm., while *P. fusiformis* is twice as long. Their luminous power is very marked, the diffused luminosity of the open sea in warmer regions being mainly due to species of *Pyrocystis* (Peridineæ playing only a subsidiary part), as that of coastal waters is largely due to *Noctiluca*.

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[1] In this paper the names appear as *P. pseudonoctiluca* Wy. T and *P. fusiformis* Wy. T., but curiously enough in the "Challenger" narrative (7) they appear as *P. noctiluca* Murray and *P. fusiformis* Murray. In this form and under this authority thay have passed into general literature, but it is, of course, the first published names that must stand.

In spite, however, of their large size, great abundance and striking luminous power, and also of the interest which attaches to the question of their systematic position, the members of this group have received but little attention, chiefly owing, no doubt, to the difficulty of obtaining suitable material. The observations here detailed were made some years ago on material obtained by pumping sea-water through bags of fine miller's silk, chiefly during a voyage to the West Indies. The results have been kept back with the hope of obtaining more material for the purpose of elucidating further such points as the method of reproduction and of nuclear division, but as this has proved fruitless, and the long promised memoir by Brandt, on the Pyrocysteæ collected by the Hensen expedition in 1892-3 (which would, no doubt, render their publication unnecessary), seems unlikely to appear, they are put forward in the present form.

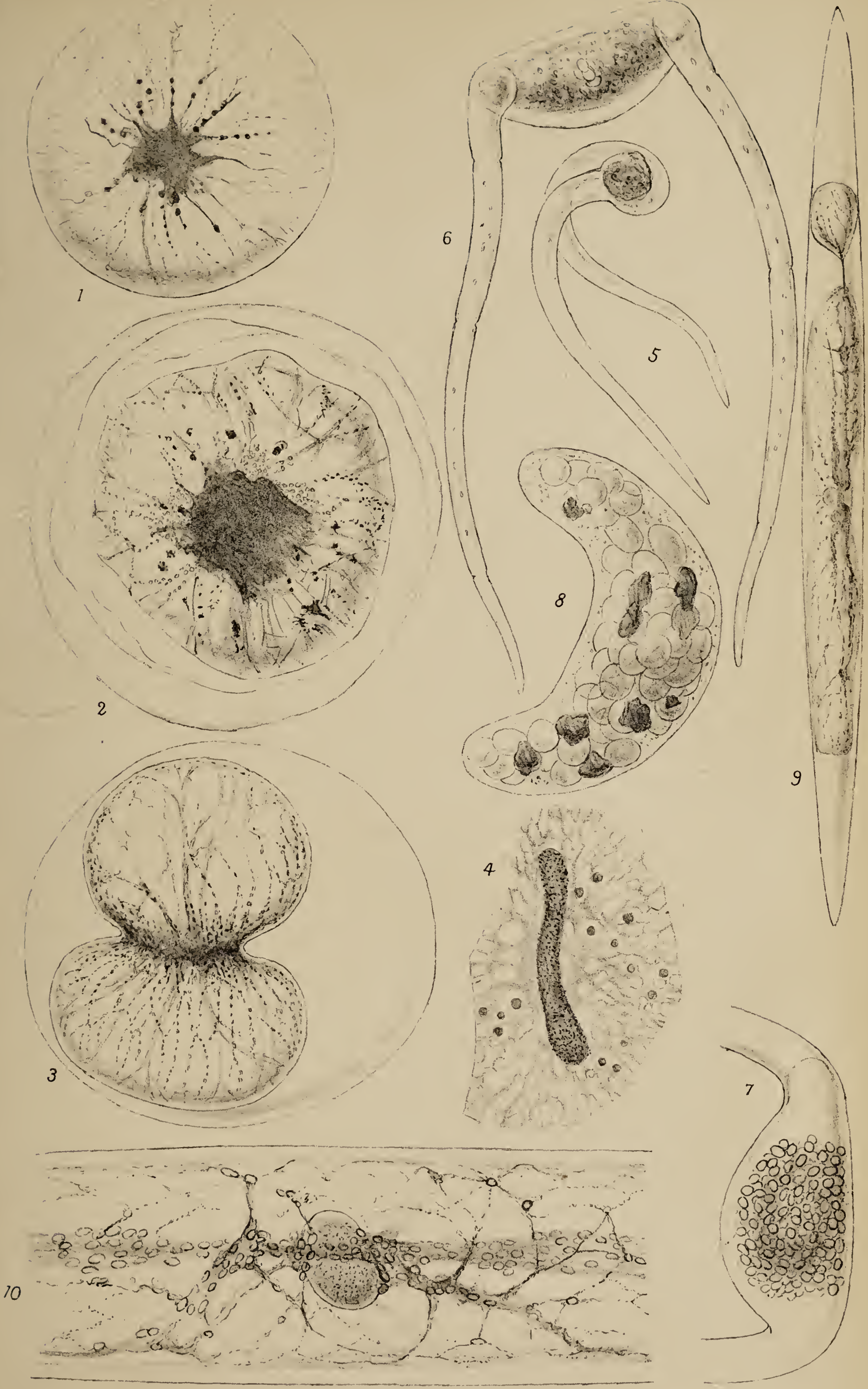
PYROCYSTIS PSEUDONOCTILUCA, Wyv. Thoms.

Structure.—A good general view of this form was given by John Murray (6) in 1876. This figure is later reproduced, with others, in the "Challenger' narrative, and there the general arrangement and colour of the protoplasm, and the cellulose wall are noted and several stages of division figured, the presence also of a large nucleus is mentioned, but no detailed account is given of the structure of the organism. The cell is perfectly spherical in form, varying considerably in size, but reaching a diameter of 0.5 mm. (sometimes slightly more) and being just visible to the naked eye. Surrounding the whole is a very distinct and beautifully translucent glassy membrane of extreme tenuity not measuring more than 0.5μ in thickness. The wall gives clearly the reactions of cellulose, it dissolves completely and very readily in ammoniacal copper oxide, it disappears without leaving any trace in strong sulphuric acid, and with chlor-zinc-iodine gives not a blue but a reddish purple colour; the colour produced in the last reaction suggests that the cellulose may be present in a slightly modified form. When the organism was first discovered, the wall, owing, no doubt, to its glassy appearance, was considered to be of siliceous nature, and the genus was accordingly placed among the Diatoms, but later, in the "Challenger" narrative (7), the true nature of the wall was recognised. No projections were observed upon the wall, such as are shown in the "Challenger" figures.

In the normal condition of the cell the main portion of the protoplasm is collected at one pole of the sphere, close against the wall (fig. 1); from this mass, which contains the nucleus, arise a number of radiating strands of protoplasm of varying thickness, the thicker ones appearing to run peripherally and the finer ones more centrally. The strands traverse a large central vacuole, and are connected with a thin layer of protoplasm which lines the wall. By far the the larger number of specimens, however, in a collection are in a more or less contracted condition, some of them only to a slight extent, as in fig. 2, but others show no radiating strands and have nearly all the protoplasm collected in a single more or less spherical clump. This contraction is, no doubt, artificially produced, and is probably brought about by the shaking and jostling to which the cells are subjected by the method of collection. The protoplasm, however, does not separate itself completely from the wall, for in even the extreme state of contraction mentioned above, a thin layer of protoplasm is always to be found in close apposition to the membrane. The layer is easily over-looked, but it can always be made to separate itself from the wall by withdrawing water from the cell by means of dilute glycerine; it is clearly shown in fig. 2, where it has shrunk completely away from the wall and has become somewhat folded.

The whole protoplasm, including the radiating strands, appears in the living state of a yellow-brown colour, of a tint like that of the colouring matter of diatoms, but when the cell is dying the colour becomes yellowish-green. The colouring matter is really confined to small homogeneous chromatophores which are usually oval in shape. John Murray (7) states that the nucleus, which lies in the polar mass of protoplasm and is completely obscured by it, is of large size, but he gives no indication of its shape. On making sections through the organisms it is seen, in the resting state, to be a narrow elongated body (fig. 3) somewhat sinuous in shape; it exhibits, not a network but a coarsely granular appearance.[1] Its behaviour during division has not hitherto been traced.

[1] From one or two observations made it would appear that there exists, beside the nucleus, a body of an archoplasmic (kinoplasmic) nature, but the material did not suffice to render this certain by following the details of division.



Highley del. et lith. imp.

Observations on the Pyrocysteæ.

The protoplaplasm contains besides the chromatophores a number of larger and smaller globules lying in the polar mass and also distributed along the strands; they become intensely black under the influence of osmic acid and are obviously of an oily nature, they are shown in the "Challenger" figures, and are well seen in figs. 1 and 2. Lying also in the protoplasm are sometimes to be seen a number of clear refractive bodies of an oval shape which are quite unaffected by osmic acid. These bodies will be considered later when dealing with some of the other species of *Pyrocystis* in which they are both larger and much more numerous.

Reproduction.—John Murray (7) in the "Challenger" report, figures a few stages in the multiplication of *P. pseudonoctiluca*, which, as far as is known, divides by simple fission. A number of cases were met with in my material in which the protoplasm was contracted away from the wall, and partially constricted into two balloon-shaped portions joined together by a bridge of protoplasm (fig. 4). At this stage I have been able to observe that nuclear division has already taken place, the two daughter nuclei both lying in the connecting bridge of protoplasm, but separated by an appreciable distance. In a few cases stages, were observed, as figured in the "Challenger" report, in which two small individuals are to be found within the parent wall. Nothing further is known as to its reproduction.

Distribution.—As mentioned earlier, *P. pseudonoctiluca* is found in all tropical and sub-tropical waters; according to John Murray (7) wherever the temperature is over 68° or 70°F, and the specific gravity of the water is not lowered by the presence of coastal or river water. I have found it as far north as 34° 30′N in the Atlantic in November when the water was at a temperature of 60°F. An exceptional case is that of the Bay of Funchal, where, according to the "Challenger" report it is to be found at the surface all the year round. The Antarctic ship "Discovery" was able to confirm its presence in that locality in August, 1901.

It often occurs in considerable abundance, Schütt (8) calculates, from observations made during the Hensen expedition, that in the Florida stream as many as 50,000 are to be found in one square mile.

Luminosity.—When a "catch" of plankton containing this species is placed in a vessel, they do not sink to the bottom, as does the rest of the "catch," but remain floating free near the surface and shine out for a few seconds as points of bluish light directly a slight shake is given to the vessel, for, as with *Noctiluca* and other luminous organisms, *Pyrocystis* when floating quietly gives out no light at all. An attempt was made to observe them under the microscope by their own light in order to determine, if possible, the portion of the cell from which the light arose. The time during which they normally remain luminous, after shaking, is hardly sufficient for the purpose, but by stimulating them artificially the period of luminosity can be much prolonged.

By the addition of 1% acetic acid, in quantities sufficient to bring the fluid in which the *Pyrocystis* is floating up to .05%, the individuals, on shaking, both shine more brightly and remain shining for a longer period. Quinine dissolved in acetic acid has the same effect, but absolute alchohol gives the most marked results. A few drops of this fluid added to 15 cc. of water containing *P. pseudonoctiluca* has some stimulating action, for on shaking they shine out more brightly than normal specimens and remain in a luminous condition longer; but the best results are obtained only by the use of much larger quantities. On adding very gently *one-third* of its volume of absolute alcohol to sea-water containing this form and various Peridineæ, and mixing the fluid carefully, a few specimens of *Pyrocystis* shine out brightly, but the full effect of the alcohol is only produced on violent shaking, the fluid then glows as one mass and remains luminous for two to four minutes. A part of this luminosity is due to small Peridineæ, but *Pyrocystis* can be distinquished as large and exceptionally brilliant spots in the glowing mass. It is strange that such a large quantity of alcohol should be required, it can only be explained by the fact that fluids penetrate very slowly through the wall, as is shown by an experiment in which some specimens of this species were allowed to fall into 0.5% chromic acid, in this fluid they remained luminous for five to ten seconds. Luminous specimens of *Pyrocystis* which have been stimulated by alcohol, can be placed on a slide and observed by their own light under a low power of the microscope in the dark. On comparing later such a view with that obtained with transmitted light, it appears that the radiation arises from the mass of protoplasm surrounding the nucleus. The specimens observed were, however, in a contracted condition, so that it may be that in a normal state the protoplasm generally may be luminous, as in *Noctiluca*. John Murray (7) simply states that "Pyrocystis is strongly phosphorescent, the light proceeding from the nucleus," but the latter statement can hardly be accepted without a considerable body of evidence. It is quite out of analogy with other luminous organisms, and would be a matter of considerable difficulty to prove in this species, where the nucleus is imbedded in a mass of protoplasm. When the organism is crushed between the fingers the crushed substance continues luminous for a few seconds (as is the case with the *Noctiluca*) ; and also when exposed and drying it in the air, it gives out light and remains luminous for a short time.

Alcohol and other chemical substances are usually described as direct agents in the production of the luminosity of organisms such as *Noctiluca*, but in *Pyrocystis*, at least, it would seem that alcohol does not act so much directly—for on merely mixing it with the water containing the organisms, very little effect is produced—but, by raising the irritability of the protoplasm, causes it to re-act more violently to the shaking stimulus. The mechanism of light production in this and other luminous organisms is, of course, quite obscure. It is, however, interesting to note that a considerable number of chemical bodies, which are to be found in living organisms, such as lecithin, cholesterin, ethereal oils, grape-sugar, etc,, under certain circumstances become luminous, and that their luminosity is increased by shaking. The light produced in these cases depends on slow oxidation, and it is therefore possible to imagine that the luminosity of *Pyrocystis* and other organisms depends on the presence in the cell of these and similar substances; the effect of shaking, etc., being to bring about more rapid oxidation, either by the increased supply of oxygen, or perhaps by some direct effect on the irritability of the living protoplasm. On the death of the cell-substance, all luminosity seems to disappear. (For an interesting discussion on the luminosity of *Noctiluca*, see Bütschli (1).

P. FUSIFORMIS, Wyv. Thoms.

This species, as it name implies, is spindle-shaped in form, and attains to a length of 1mm. Fig. 9 shows it in the resting and and slightly contracted state, while in the "Challenger" narrative two figures are given of what is apparently a stage in the process of division. The nucleus is more or less spherical in shape (fig. 10), but apart from this and the external form, the general arrangement of the cell is similar to that of the first described species. There is the same collection of protoplasm at one point of the cell, in this case the middle of the long axis, from which cytoplasmic strands radiate out to the rest of the cell. A large number of oil globules are to be observed both around the nucleus and along the strands (fig. 10). The general colour of the protoplasm is the same as that of *P. pseudonoctiluca*, but the form of the chromatophores I have not been able to make out. Nothing is known as to its reproduction. According to John Murray, this species is usually found in company with *P. pseudonoctiluca*, but is not nearly so abundant. I have observed it in the Atlantic, as far north as 43° N. According to the same authority it is exactly similar in luminous power to the first described species.

P. Lunula, Schütt.

Schütt (9) in the first part of his studies on the Peridineæ of the Hensen expedition, has given some good figures of this form under the name of *Gymnodinium lunula*, but as the description of the new species found during that expedition are held over for a second part, which has not yet appeared, no information, other than the explanation of plates, is supplied. Later, in Engler & Prantl's "Pflanzenfamilien," Schütt (10) removes this form from *Gymnodinium*, and places it in the genus, *Pyrocystis*, to which there seems little doubt that it belongs, for except for its curved shape, it agrees very closely with *P. fusiformis*. Schütt also figures a few stages of flagellate spore formation in this species, which will be discussed later in relation to the question of the systematic position of the family.

P. Hamulus, Cleve.

Cleve (2) in 1900, figured in outline an organism which he doubtfully placed in the genus *Pyrocystis*, and to which he gave the above name. This species has been familiar to me since 1898, and there can be little doubt that it is a true *Pyrocystis*. It is the form which appears in 1899, in the list attached to a paper on *Atlantic* Peridineæ, by Murray and Whitting, as *Pyrocystis bicornis*, Blackmn (see synopsis). As this was a mere *nomen nudum*, without figure or description, it must give way to the later name of Cleve, to which a figure was attached, though no description. The general form is well shown in Figs. 5 and 6; the body is irregularly ovoid, and is prolonged into two long, stout, tapering and curved horns. The nucleus lies in the centre of the body, and the protoplasm clearly extends into the horns, though the material under observation was not sufficiently well-fixed to enable one to determine its exact arrangement. The average length of the body is about 80μ, and that of the horns about 250μ. This species has been observed in the Indian Ocean and in the Atlantic, Cleve (3), where it ranges up to 37° N.

Amylum-bodies. In all the four species above mentioned, there are often to be found a number of clear refractive bodies of a spherical oval or rod shaped form They are fairly often to be seen in *P. fusiformis*, but the most striking case observed was that of *P. lunula*, where on one occasion they were seen to fill nearly the whole cell, hiding from view most of the protoplasm (fig. 8). In *P. hamulus*, the granules are usually of small size, but sometimes in this species also they occur in such numbers as to obscure the protoplasm (fig. 7); in *P. pseudonoctiluca* also, as mentioned earlier, the bodies are sometimes found, but only in small numbers. The bodies are not of a proteid nature, for with osmic acid they give no reaction; but their behaviour with iodine is peculiar. With a fairly strong solution of iodine in potassium iodide, they take on at first a deep brown colour, which soon becomes almost black; if when in this condition they are washed with water, they lose part of their colour and become of a reddish-purple tint. At the same time they swell up under the action of the water, and show a differentiation into a peripheral more dense part and a central apparently more watery part. Their exact nature must, for the present, remain uncertain, but they are probably to be classed with the so-called Amylum-bodies which have been observed in a few of the Peridineæ. Whether either they or the numerous oil globules which are always present have any reason to be considered as an assimilation product of the chromatophores, is an interesting question which cannot yet be answered.

The systematic position of the Pyrocysteæ.—On the first discovery of *P. pseudonoctiluca* and *P. fusiformis* it was believed that their wall contained silica, and they were therefore classed by John Murray (6) with the Diatoms. When this view was given up later, and the wall shown to consist of cellulose, Murray (7) put forward no further view as to the affinities of the genus.

A number of zoologists have, however, for some time, considered *P. pseudonoctiluca* to be merely an encysted condition of *Noctiluca*. Saville Kent (4) was the first to put forward this theory, but it owes its support to the distinguished authority of Bütschli (1). This observer states that, after the examination of some material supplied to him by John Murray, he must support the view of Saville Kent. He bases his view on the belief that no cell-wall is present, and that there cannot be a siliceous sheath, for no trace of it is left after the action of strong sulphuric acid. That no *siliceous* wall is present is very true, but how Bütschli came to overlook the presence of the cellulose wall is difficult to understand; of its existence there can be no doubt, it is always very obvious, both from its general appearance and its reactions.

The absence of flagella, the presence of yellow-brown chromatophores and of a continuous cellulose wall, are all characters which separate it from *Noctiluca*; there seems little doubt that, had Bütschli recognised the wall, he would not have connected *Pyrocystis* with that organism. The striking difference of distribution of these two organisms would almost alone negative any idea of their relationship. They are never found together, *Pyrocystis* being nearly always pelagic, while *Noctiluca* is nearly always coastal. The *only* points of similarity are their arrangement of protoplasm and their luminous power. The depression in the protoplasmic substance of *P. pseudonoctiluca* shown in Murray's figure is not a normal condition (it may be the first indication of division of the cell), and cannot be compared, as Bütschli supposes, to the peristome depression of *Noctiluca*. In face of this evidence the view that *Pyrocystis noctiluca* is a stage in the life history of *Noctiluca* must be abandoned.

Granting, however, the vegetable affinities of Pyrocystis, there is still great doubt as to its systematic position. owing to our ignorance of the life-history of the various forms.

Schütt (8), an account of the resemblances of *Pyrocystis* with certain encysted states of Peridineæ, would place them near that group. He admits, however, that they have certain resemblances to the simple Desmids, though they differ in the arrangement of their protoplasm, and in the form and colour of their chromatophores.

Haeckel (4) places *Pyrocystis* in the group Murracyteæ (Pyrocystales), in the Paulotomeæ division of the Algæ. He thinks that they are probably a group of very simple structure and of great antiquity. Believing erroneously that the wall contained silica, he suggests that they may have given origin to the Diatoms.

Schütt (9, 10) figures, as mentioned earlier, the development of *Gymnodinium*-like flagellate spores with a horizontal furrow, in the cell of *Pyrocystis lunula* and on that account places the Pyrocysteæ with *Gymnodinium* in the Gymnodiniaceæ, a division of the Peridiniales. As Schütt's figures are published without comment or discussion, criticism is a matter of some difficulty, but it must be pointed out that no trace of a flagellate stage has been observed in any of the other four species of *Pyrocystis* (in spite of the great abundance of *P. pseudonoctiluca*), and that, but for the somewhat meagre evidence provided by these figures of Schütt, the Pyrocysteæ would have to be considered as an algal group of quite unknown affinities.

SYNOPSIS OF SPECIES.

Pyrocystis—Wyv. Thoms ex J. Murray.

P. pseudonoctiluca, Wyv. Thoms. ex J. Murray, Proc. Roy. Soc. Lond. Vol. xxiv. 1876, page 533, pt. xxi, fig. 1. (Syn. *P. noctiluca*, Murray, "Challenger" Report, Vol. I. pt. 2, 1885, p. 935.)

Cell spherical; main portion of protoplasm collected at one pole; chromatophores, small oval plates; nucleus elongated.

P. fusiformis, Wyv. Thoms, ex J. Murray, Proc. Roy. Soc. Lond. Vol. xxiv., 1876, page 533, pl. xxi., fig. 2 (Syn. *P. fusiformis*, Murray, "Challenger" Report, Vol. I., pt. 2, 1885, p. 935.)

Cell spindle-shaped; main portion of protoplasm central; chromatophores, shape?; nucleus round.

P. lunula, Schütt. Engler and Prantl. Pfanzenfamilien *Peridin*, ex Teil I. Abt. 1, 1896, p. 3, fig. 2. (Syn. *Gymnodinium lunula* Schütt, Die Peridineæ des Plankton Expedition, Teil I., 1895, pl. 24, fig. 80.)

Cell half-moon shaped; chromatophores mostly short rods; nucleus round, central.

P. hamulus, Cleve, K. Vetensk Akad Handl, vol. 34, No 1. 1900, pl. vii., fig. 23, (Syn. *P. bicornis*, Blackmn, Murray and Whitting, Trans. Linn. Soc. Lond., 2nd ser. Botany, vol. 5., pt. 89, 1899.)

Cell two-horned; chromatophores, shape?; nucleus round, central.

P. lanceolatus, Schröder, Mitth Zool. Stat. Neapel., vol. xiv. 1900, p. 13, fig. 11.

Cell elongated, pointed at both ends, chromatophores? nucleus? (This species I have not seen, but there is nothing in the figure or few words of description given by Schröder, to distinguish it from *P. fusiformis*.)

LIST OF REFERENCES.

1. Bütschli, O. Protozoa in Bronn's Klassen, etc., Bd. I., Abt. 2, 1885, p. 1062 and p. 1088-1095.
2. Cleve, P. T. Notes on Atlantic Plankton organisms, K. Vetensk. Akad Handl, vol. 39, No 1, 1900, p. 19.
3. ,, ,, The seasonal distribution of Atlantic Plankton Organisms. Göteberg, 1901, p. 360.
4. Haeckel, E. Systematische Phylogenie der Protisten u. Pflanzen, 1894, Teil I, p. 109.
5. Kent, Saville A Manual of the Infusoria, London, vol. 1, 1880, p. 399.
6. Murray, J. Proc. Roy. Soc., Lond., vol. 24, 1876, p. 533.
7. ,, ,, "Challenger" Reports, Vol. I., Pt. 2, 1885 p.p. 935-938.
8. Schütt, F. Das Pflanzenleben der Hochsee. Kiel u. Leipzig, 1893, p. 38.
9. ,, ,, Die Peridineen der Plankton Expedition. Teil I. Kiel u. Leipzig, 1895, fig. 80.
10. ,, ,, Die natürlichen Pflanzenfamilien Teil I., Abt. Ib., 1896, p. 3.

DESCRIPTION OF PLATE IV.

Figs 1-5.—*Pyrocystis pseudonoctiluca,* Wyv. Thoms.

Fig. 1.—A normal uncontracted specimen, after the action of osmic acid, × 180.

Fig. 2.—A similar specimen, but slightly contracted, × 170.

Fig. 3.—A stage of division of the cell, × 145.

Fig. 4.—Section through central mass of protoplasm showing elongated nucleus; the deeply staining granules are of uncertain nature, × 580.

Fig. 5.—*P. hamulus* Cleve, × 210.

Fig. 6.—Another specimen, × 380

Fig. 7.—Central portion of *P. hamulus* showing a collection of "amylum" bodies.

Fig. 8.—*P. lunula* Schütt; showing large "amylum" bodies; the dark masses are protoplasm blackened by the action of osmic acid, × 820.

Fig. 9.—*P. fusiformis* Wyv. Thoms., a slightly contracted specimen, × 90.

Fig. 10.—Central portion of same specimen showing the nucleus, oil bodies and reticulate arrangement of protoplasm, × 380.

A REVISION OF THE CLASSIFICATION OF THE GREEN ALGÆ

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(*continued from page* 168.)

Fam. I. Archidesmidiaceæ.

Cells cylindrical, elongated, chromatophores various, with no definite planes of symmetry, constituent *cells, united* end to end *in filaments*, which break up before conjugation takes place.

[It seems most natural to separate the two following genera from the rest, since they are clearly far less specialised. They strongly resemble *Mougeotia* and *Spirogyra* among the Zygnemoideæ, and very probably stand close to the common ancestors of these and the *Eudesmidiaceæ.*]

Genera.

1. *Gonatozygon.* De Bary, 1858.

   Chromatophore single, axile, band-shaped, bearing a single row of pyrenoids. Cell-wall covered with minute warts.

2. *Genicularia.* De Bary, 1858.

   Chromatophores several, parietal spirally-wound bands, each with a single row of pyrenoids.

Fam. II. Eudesmidiaceæ.

Cells free or connected by their ends into threads, sometimes polysymmetrical and cylindrical or spindle-shaped, but usually symmetrical about only three planes at right angles to one another.

Sub-Family. I. Penieæ.

Cells free, typically cylindrical or spindle-shaped, straight (rarely curved), usually without equatorial constriction.

Genera.

1. *Cylindrocystis.* De Bary, 1858.

   Cells cylindrical or oval, straight with rounded ends. Chromatophores two, one at each end of the cell, each consisting of a rounded body, containing a single pyrenoid, and numerous diverging rays.

2. *Mesotænium.* Nägeli, 1849.

   Cell-form as in *Cylindrocystis.* Chromatophore consisting of an axile plate with one pyrenoid.

3. *Ancylonema.* Berggren, 1870.

Cell-form as in *Mesotænium*, but with a curved parietal chromatophore and purple cell-sap. Cells united in short threads.

4. *Penium.* De Bary, 1858.

Cells straight, cylindrical or slightly flattened, with somewhat rounded ends and without equatorial constriction. Chromatophore consisting of radially diverging plates united in the central axis of the cell, which contains a single row of pyrenoids; a vacuole often present at each end of the cell.

5. *Pleurotænium.* Nägeli, 1849.

Cells straight, cylindrical, slightly narrowed towards the ends. On each side of the shallow equatorial constriction a wave-like transverse swelling runs round the cell. Chromatophores consisting of several parietal bands each with several pyrenoids.

6. *Docidium.*

Cells much as in *Pleurotænium*, the ends sometimes bearing branched or unbranched processes or lobes. Chromatophore constructed as in *Penium*.

7. *Spirotænia.* Brébisson, 1841.

Cells straight or slightly bent, cylindrical with rounded ends, or spindle-shaped, unconstricted equatorially. Chromatophore of one or more parietal, spirally-wound bands, each with one or more pyrenoids.

8. *Closterium.* Nitzsch, 1817.

Cell semilunar or sometimes S-shaped, with tapering ends, symmetrical about the equatorial plane and one longitudinal plane only, without equatorial constriction, with terminal vacuoles. Chromatophore of radially diverging plates, united in the centre as in *Penium*.

Sub-Family II. Cosmarieæ.

Cells typically oval in general outline, with a well-marked equatorial constriction, slightly or considerably flattened in a longitudinal plane.

9. *Cosmarium.* Corda, 1835.

Cells usually free, oval or round, with a well-marked equatorial constriction. Chromatophores two, each of four or more plates, united in the centre of the semicell, and containing one or two pyrenoids.

10. *Cosmocladium.* Brébisson, 1856.

Like *Cosmarium*, but cells united by pairs of mucilaginous threads to form branched colonies.

11. *Oocardium.* Nägeli, 1849.

Adhering to the surface of rocks and forming a calcareous incrustation composed of a number of parallel vertical tubes, the free end of each of which is inhabited by an individual cell.

Cells ovoid, equatorial constriction slight, parallel to the axis of the tube. Chromatophores two, one in each semicell, each composed of a central body containing a pyrenoid and of radiating plates; narrowed towards the lower end so that the cell is not symmetrical about the plane perpendicular to the axis of the tube, the lower part of the cell containing the nucleus and the narrowed ends of the chromatophores.

12. *Tetmemorus.* Ralfs, 1845.

Cells cylindrical or spindle-shaped, with an aquatorial constriction and a narrow furrow at each end. Chromatophore axile with a single row of pyrenoids.

13. *Euastrum.* Ehrenberg, 1831.

Cells elongated or broadly elliptical, somewhat flattened, and with a deep equatorial constriction. Outline of the cell with symmetrical rounded lobes and a well marked furrow at each end Chromatophore axile composed of longitudinal radiating plates.

14. *Micrasterias.* Agardh, 1827.

Cells straight, circular or broadly elliptical, flattened. Each semicell three-lobed, the terminal lobe entire or bayed, the laterals symmetrically furrowed or cut. Chromatophore an axile plate in the plane of the cell, sometimes with subordinate plates, as in *Euastrum.*

15. *Arthrodesmus.* Ehrenberg, 1836.

Like *Cosmarium*, but with two or four long processes arising from the wall of each semicell.

16. *Holacanthum.* Lundell, 1871.

Cells oval or nearly round, sometimes angular, with a deep equatorial furrow and two rows of long hornlike unbranched processes on the edges and a swelling on each side of the semicell. Chromatophores parietal, platelike, each with a pyrenoid, four or six in each semicell.

17. *Schizacanthum.* Lundell, 1871.

Like *Holacanthum*, but marginal processes branched. Several pyrenoids in each chromatophore.

18. *Staurastrum.* Meyen, 1829.

Cells oval, with a deep equatorial furrow. In end view, usually triangular, quadrangular or polygonal, often with the angles continued into arms. Chromatophore one in each semi-cell, consisting of a central body with a pyrenoid and diverging plates, of which two run parallel into each angle.

19. *Pleurenterium.* Lundell, 1871.

Like *Staurastrum*, but with parietal chromatopores, each containing several pyrenoids.

Sub-Family III. Filamentæ.

Cells always united by their ends to form filaments.

20. *Spondylosium.* Brébisson, 1845.

Cells roughly oblong, with rounded or straight ends, oval or triangular in end-view. Chromatophore axile, consisting of a central body containing a pyrenoid, and four or six diverging plates in each semicell.

21. *Onychonema.* Wallich, 1860.

Cells flattened, with a deep equatorial constriction. Semi-cells oval or kidney-shaped, with two processes by which the cells are connected into slightly curved threads. Chromatophore of four plates diverging from a pyrenoid in each semicell.

(*To be continued.*)

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MENDEL'S LAWS AND THEIR PROBABLE RELATIONS TO INTRA-RACIAL HEREDITY.

By G. Udny Yule.

THE two volumes[1] that are the immediate occasion of these articles have more in common, besides their authorship, than appears from their respective titles; both deal solely with Mendel's Laws of Hybridisation, to which so much attention has been recently directed. The "Report to the Evolution Committee" of the Royal Society contains an account of experiments, begun apparently with other objects, but continued with a view of further testing the scope and validity of the laws. These experiments include crosses between species or varieties of *Lychnis*, *Atropa*, *Datura* and *Matthiola*, together with some observations on poultry. Generally speaking the results are in accordance with Mendel's rules, although Mr. Bateson and Miss Saunders, like other observers, found some difficulties and exceptions, notably in the case of the *Matthiola* hybrids and in the experiments with poultry. The Report on these experiments is preceded by a short account of the work of Mendel himself, and that of Correns, De Vries, and Tschermak, and is followed by some forty pages on "The Facts of Heredity in the light of Mendel's discovery." The second volume on "Mendel's Principles of Heredity" consists of two parts, the first containing a translation of Mendel's papers, with an introduction; the second, with the sub-title "A Defence of Mendel's Principles of Heredity," being a reply to Professor Weldon's article "On Mendel's Laws of Alternative Inheritance in Peas," which appeared in the January number of "*Biometrika*."

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[1] (1) Royal Society. Reports to the Evolution Committee. Report I. Experiments undertaken by W. Bateson, F.R.S., and Miss E. R. Saunders. 1902.

(2) Mendel's Principles of Heredity: a Defence; by W. Bateson, F.R.S. Cambridge: at the University Press, 1902.

The facts collected by Mr. Bateson and Miss Saunders in the "Report," have considerably extended the area of application of the highly remarkable laws discovered by Mendel, as well as to a minor extent the list of exceptions; they do not, however, appear to throw much fresh light on the fundamental nature of the laws themselves. The sections of the two volumes which do appear to call for criticism and review are those relating to the bearing of Mendel's results on the conceptions of heredity in general, and on the work of Mr. Francis Galton and Professor Pearson in particular. Mr. Bateson devotes many words to these questions, but one cannot help feeling that his speculations would have had more value had he kept his emotions under better control; the style and method of the religious revivalist are ill-suited to scientific controversy. It is difficult to speak with patience either of the turgid and bombastic preface to "Mendel's Principles," with its reference to Scribes and Pharisees, and its Carlylean inversions of sentence, or of the grossly and gratuitously offensive reply to Professor Weldon and the almost equally offensive adulation of Mr. Galton and Professor Pearson. A writer who indulges himself in displays of this kind loses his right to be treated either as an impartial critic or as a sober speculator. Mr. Bateson is welcome to dissent from Professor Weldon's opinions, but it would have been well if he had imitated the studied moderation and courtesy of his article.

Mr. Bateson may no doubt congratulate himself on a *succès de scandale*, but it is difficult to see that his "Defence" attains any worthier goal. Apart altogether from the question of good manners, the entire history of scientific and philosophical controversy would have taught a more judicious disputant that personal polemic is the very worst method of arriving at truth; an attack of this kind can do nothing but distract attention from the scientific question and concentrate it upon ephemeral personalities. If Mendel's laws are of the importance that Mr. Bateson claims, the general acknowledgment of that importance is bound to come, whether one writer or another is sceptical or not. Nor does it appear that the responsible advisers of the Cambridge Press can be acquitted of a certain failure to appreciate the dignity that should belong to a University Press, in allowing the publication of a volume containing insinuations such as those Mr. Bateson has permitted himself to put on paper.

The fact that I am inclined to agree with Mr. Bateson as to the *possibly* very high importance in practice and theory of Mendelian phenomena only makes me regret the more the defects of his style and manner of treatment. The assumed separation of characters in the germ cells of the hybrid on which Mendel based his explanation of the results he had observed, *may*, as Mr. Bateson suggests, very possibly be proved in the future to hold good over a much wider field than has yet been experimentally tested. Mendel's phenomena *may* bring us to revise fundamentally some of our conceptions of heredity, they may suggest new directions in which to seek for solutions of some problems of the cell, they may throw fresh light on the process of fertilization in general, and on the nature of variation. But it must be remembered that at present Mendel's Laws are only known to hold for cases of hybridisation, and do not appear to hold invariably then; in the present state of our knowledge it is speculation—legitimate, even desirable, but still speculation, pure and simple,—to postulate the existence of similar phenomena when breeding only with a pure strain. It is well that such a possibility should be borne in mind, and that the whole case should be fully and impartially discussed and considered. Yet Mr. Bateson has taken the very action most effectually calculated to render calm criticism and unbiassed judgment impossible, as he may by now have realized. The language of unbridled enthusiasm and lavish abuse creates nothing but mistrust. It is most regrettable that this convenient translation of Mendel's papers should appear in so disadvantageous a context. Many of the conclusions at which Mr. Bateson arrives seem so entirely due to his misunderstandings of various passages in the writings of Mr. Galton and Professor Pearson that I propose, in the first place, to deal not with Mendel's work at all, but with that of the statistical or biometrical school. Having cleared the ground in that direction, it will be easier to institute comparisons between the results obtained by the two schools, and to discuss the bearing of the two classes of observations on each other.

There has always been a good deal of misunderstanding between biologists in general and those who have done pioneer work in the use of statistical methods, due in great part, I believe, to the fact that the two do not use such terms as *heredity*, *variation*, *variable*, *variability*, in precisely the same signification. The employment of quantitative methods necessarily leads to the use of such expressions in a more precise signification, and hence to a greater or less amount of divergence from the older and more popular usage. "Heredity" is, for instance, most usually defined by biologists as referring generally to all phenonema covered by the aphorism "like begets like." In this sense it denotes *inter alia* the phenomenon of the constancy of specific or racial types and of sexual characters; a character may be said to be *inherited* when it always, in one generation after another, is one of the characters of the species, of the race, or of the one sex of the race, as distinct from the other. The species, race or sex, so to speak, "begets its like" as a whole. But then a further question remains; even if the type of the race is constant, do *individual* types within the race beget their like? In so far as any *individual* diverges in character from the mean of the race do his offspring tend to diverge in the same direction, or not? It is to this question that statisticians have confined themselves, and they speak of a character being "inherited" or not according as the answer to the question is yes or no—they deal solely with what we may term "*individual* heredity."

The quantitative procedure is in its essence extremely simple, though the actual work may often be rather lengthy. A series of measurements is made of some one variable character, *e.g.* a length, in parents and in their offspring, noting the individual families (the more the better) and not merely measuring the first generation as a whole and then their offspring as a whole. From these measurements an equation is derived, giving, as nearly as may be, the mean character of the offspring in terms of the character of the parent. Supposing X to be the character in the parent, Y the mean character in the offspring, then the simplest form of such equation is:—

$$Y = A + B. X. \qquad (1)$$

Where A is a dimension of the same order as X or Y, and B is a number that will vary from case to case. We have for instance from the data collected by Mr. Galton for inheritance of stature in man, reduced by Professor Pearson, the equation relating mean stature of sons and stature of father:—

$$Y = 31{\cdot}10 + {\cdot}45\,X. \qquad (2)$$

i.e. the mean stature of sons is 31·1 inches, together with nine-twentieths of the stature of the father (also in inches of course). The father's stature is thus some guide to the stature of his offspring; it enables us to form a closer estimate of their stature than we could from a mere knowledge of the mean characters of the race, and we may therefore say that stature is an *inherited* character. The sons do diverge from the race-mean in the same direction as their parent. Quite generally, the statistician speaks of a character as *inherited* whenever the number or "constant" B is greater than zero; if it does not differ sensibly from zero the character is held to be non-heritable, quite apart from the question whether the mean is more or less constant from one generation to the next, a consideration which does not affect the conception of *individual* heredity.

It is important that the biologist should realise this distinction between individual heredity and race-heredity, or as I should prefer to term it, constancy of type; for, although the two phenomena must be in some way related through the processes of reproduction and growth, approximate constancy of type is not only logically, but, I believe, actually quite compatible with very slight individual inheritance, the type being maintained the same by the constancy of external conditions and the action of selection. Moreover, and this is the most important point, the maxim "like begets like" does not hold in the same rigid sense for the individual and the race. One generation of a race is (approximately speaking) the same as the preceding; apart from such changes as are hardly revealed except by measurement, the mean of the offspring is that of the parents. It would seem natural perhaps to assume that the same law holds for individual types within the race—why should an isolated group of individuals behave differently from the race as a whole? Yet the assumption would be false; the offspring of any abnormal individual, any individual differing from the mean of the race, *are always, on the average, more mediocre than himself.* In the terms of our "estimating equation" (1), this means that the constant B is always less than unity—always a fraction, If the offspring simply centred round the parental type we should have

$$Y = X$$

always. For stature in man the value of B is about 0·3 to 0·5; for a certain character in *Daphnia* Warren found B = 0·6, for other characters in an *Aphis*, 0·54, 0·5, and 0·36, the reproduction being parthenogenetic in both these cases; for vegetative reproduction in *Lemna minor* I find, so far as the results are reduced, B = 0·25 to 0·60, roughly speaking. This phenomenon of the relapse of the offspring from the parental type towards mediocrity is termed *regression.* Regression and not constancy of type is for the statistician, the fundamental phenomenon of heredity and the prime fact to be explained by any physical theory. The absolute lack of any mention of the subject in most biological theories makes them seem, to him, in so far, curiously unreal.

It is not essential for the application of such "estimating equations" as (1) or (2) to the study of heredity that the variation of the character concerned should be strictly continuous as in the case of stature in man. The method is equally applicable to any form of variation in a scalar series, even when such variation proceeds by a series of discrete steps. The variation of petals, sepals, and other floral parts, and of numbers of offspring, may be quoted as familiar instances. Even in such cases as stature, discontinuity is, in point of fact, nearly always introduced by the observations being grouped, or the measurements being only taken to some considerable unit of the scale, *e.g.* to the nearest half-inch or quarter-inch. Between real continuity—a continuity that appears to be unbroken with the most careful measurements possible—and the discontinuity of a scalar series proceeding by successive equal units there is therefore no important distinction. The same method and conceptions apply, the same law of regression must hold.

A distinction arises, however, if no scalar series exists, but the race is simply divided into two exclusive classes, the one possessing some attribute, the other not; as one may divide a race of men into deaf-mutes and normals, sane and insane. In such a case the statistician again speaks of the attribute as being *inherited*, if the character of the parent enables one to estimate the character of the offspring more accurately than would be possible from a mere knowledge of the general characters of the race. If the two classes be termed A's and a's, then the attribute is *inherited* if the per- of A's amongst the offspring of A's is larger than the per centage amongst the offspring of a's. This is, as before, *individual* heredity. When the biologist speaks of the transmission of an attribute common to all the members of a race as *heredity* (as the flowers of one race of plants may be white, those of another pink; the stems of one glabrous, those of another hairy), he is dealing with a quite distinct aspect of the phenonemon. I do not, of course, object to such an accepted use of the term, but wish to emphasise the distinction,

Whether, in fact, we deal with continuous variables or attributes, all the individuals observed, in any one case, must be members of one race, or else the two phenomena of race-heredity and individual heredity are superposed and confused. If, for instance, stature-measurements on a tall race and a short race were mixed, it is conceivable that there should be no individual heredity for either race taken separately, and yet the mixture would exhibit an apparent heredity due simply to the constancy of type for each race. It would be true for the mixture that the taller parents had the taller offspring, but not true for either race separately. The same thing holds good in the case of attributes. If two races be mixed, of which a large per-centage of individuals in the one case and only a small per-centage in the other, possess some attribute, it will be true for the mixture that the offspring of A's exhibit a larger proportion of A's than the offspring of a's; but this will not necessarily be true for either race separately. The two classes A and a belong, I take it, to one race when pure matings of of A's with A's may give rise to a's and vice-versâ. In the case of a continuously-variable character, all the individuals may be held to belong to one race if they cannot be divided into two classes such that pure matings between members of the one class never give rise to offspring that would be assigned to the other. The distinctions between continuity and discontinuity of variation, between inheritance of attributes and of variables do not seem to me to be of *necessary* importance for the theory of heredity; successive discontinuities may be so slight as to be undiscoverable by the most careful and repeated measurements. The real and important distinction seems to lie between the phenomena of *heredity* within the race, and the phenomena of *hybridisation* that occur on crossing two races admittedly distinct. Several of the investigations of Mr. Galton relate to the inheritance of attributes (*e g.* of temper, of artistic faculty in man, of colour in Basset-hounds), none of them (so far as I am aware) to hybridisation. It does not seem probable that either he or Professor Pearson intended the term heredity to cover such cases; I can certainly say for myself that in stating any rule to be a "law of heredity," I should not dream of implying thereby that it was a law of hybridisation.

Mr. Bateson fails to make any distinctions whatever. Mr. Galton's researches on Basset-hounds and the Galton-Pearson work on eye-colour in man (both referring to individual heredity within the race) are classed, under the general heading of "discontinuous variation," with Mendel's work on crossing distinct races of peas and Mr. Bateson's own on hybridisation of flowers and races of poultry, as if they referred to comparable matter. This does not tend to clearness. Mr. Bateson further adduces the work of *hybridisers* to rebut the generality of the Galton-Pearson law of *heredity*:—

"Not to mention moderns, these high hopes" (of the generality of the law) "had been finally disposed of by the work of the experimental breeders such as Kölreuter, Knight, Herbert, Gärtner Wichura, Godron, Naudin, and many more. To have treated as non-existent the work of this group of naturalists, who alone have attempted to solve the problems of heredity and species—Evolution as we should now say—by the only sound method—*experimental breeding*—to leave out of consideration almost the whole block of evidence collected in *Animals and Plants*—Darwin's finest legacy as I venture to declare—was unfortunate on the part of any exponent of Heredity, and in the writings of a professed naturalist would have been unpardonable." (Mendel's Principles, pp. 112-13).

The "experimental breeders" referred to never touched the questions of intra-racial individual heredity at all. The work of Darwin bears chiefly on racial heredity, and on hybridisation ; the relatively small portions on intra-racial heredity do not give information in any form which enables one to apply it to the criticism of statistical laws. In the present state of our knowledge it is impossible to confuse the subjects in so loose a fashion. Laws of hybridisation cannot be admitted as general principles of heredity until they have been proved to hold as such—the title of Mr. Bateson's volume begs the whole question—nor can laws of heredity be in general, or necessarily, expected to hold good in cases of hybridisation. "Experimental breeding" is certainly a sound method for the study of heredity: it is not the *only* sound method, for equally good material may be obtained by simple observation, as in the case of man. But if by "experimental breeding" is meant solely hybridisation (*i.e.* crossing of different races, varieties, species or genera in general), then I join issue with Mr. Bateson altogether. Experiments on crossing can give nothing but laws of crossing; it may be possible that some of these laws are applicable to the breeding of pure races, but this cannot be decided without definite trial. The work of the whole of the "group of naturalists" he mentions is valueless for the branch of work on which the biometrical school has been engaged.

So far we have dealt solely with the direct heredity between parent and offspring; now let us consider the question of inheritance from the remoter ancestry. Supposing a series of grandparents and their grandchildren to be measured as before, it is evident that we could construct an "estimating equation" just like (1), but giving the mean character of the *grand*children in terms of the character of the *grand*parent. The only difference in result would probably be, that the constant B would be somewhat reduced as compared with its value for the parental heredity. If an individual have a given abnormality of character, his offspring will *probably* (or on the average) be abnormal, but rather less so, his grand offspring again divergent, but less abnormal still. This phenomenon, that the character of the grandparent (like that of the parent) enables one to estimate the mean character of the offspring more accurately than would be possible from a mere knowledge of the characters of the race, is, in a sense, "ancestral heredity." It is not, however, what the statistician generally means by that term. In the above, the parent's character is supposed either unknown or neglected; we deal solely with grandparent and grandchildren. But supposing the character of the parent known, so that one datum for estimating the mean character of offspring is already given, a wholly new question arises, *viz.* will a knowledge of the grandparent's character enable one to increase the accuracy of estimate? If the answer to the question be in the affirmative, as it is in every case without exception which has yet been tried, then there is what may be termed a *partial* heredity from grandparent as well as parent, and it is to the existence of such *partial* heredity that statistical writers generally refer when they speak of "ancestral heredity." If X_1 and X_2 be the parental and grandparental characters, Y the mean character of the offspring, then all the experience that we have shews that if an equation be formed giving Y as nearly as may be in terms of both X_1 and X_2, *e.g.*

$$Y = A + B_1 . X_1 + B_2 . X_2 . \qquad (3)$$

the term B_2 has a very sensible value—*i.e.* the grandparent's character very sensibly increases the accuracy of estimate. This law of partial heredity from the grandparent is known to hold for fertility, length of life, and eye-colour in man, for coat-colour in horses, for one character in a *Daphnia*, three characters in an *Aphis*, and I may add, from some recent work of my own, two or three characters in common duckweed (*Lemna minor*). The list is not a long one certainly, but the characters and the genera are so extraordinarily diverse that the law must be one of very great generality.

Nor, of course, need we suppose investigations to cease with the grandparent. If a knowledge of the grandparental character increases the accuracy of estimate of the mean character of offspring, it is natural to assume that the further knowledge of the great-grandparental, great-great-grandparental, etc., characters would increase it still more, though probably in a diminishing ratio. It would be very unlikely, to say the least, that an absolute discontinuity should come in at any one generation, and that the nth ancestor should sensibly increase the accuracy of estimate while the $(n + 1)$ th should not. In the absence of such discontinuity the law of heredity (of *intra-racial individual heredity*) must be of the form

$$Y = A + B_1 . X_1 + B_2 . X_2 + B_3 . X_3 + B_4 . X_4 + \dots \quad (4)$$

where X_1 X_2 X_3, etc. are the characters of the successive ancestry and B_1 B_2 B_3, etc. a series of diminishing fractions. No investigations, so far as I am aware, have been published, that give the values of B's beyond the grandparents, but my own experiments on a small scale on *Lemna minor* give sensible positive values up to B_4—as far as I could carry the observations. Moreover such a form of law is in obvious accordance with the practice of breeders of pure stock, who judge the value of an animal for breeding purposes not by its own characters alone, nor by that and the characters of its immediate parents, but by its whole pedigree. The pedigree would be completely valueless if there were no "partial heredity" from ancestry; if B_2 B_3, etc. were all zero two animals with equally desirable values of X_1 would be equally likely to produce good offspring, even if the one had bad or mediocre ancestry and the other a good pedigree. It is difficult to suppose that the weight attached to pedigree is based on nothing but illusion, yet it is only reconcilable with a law of partial ancestral heredity such as (4). This law then, that *the mean character of the offspring can be calculated with the more exactness, the more extensive our knowledge of the corresponding characters of the ancestry*, may be termed the Law of Ancestral Heredity.

Little work has yet been done on the intra-racial inheritance of attributes, but the form which the law of ancestral heredity would take in such a case is fairly obvious. It might be written in the form (to use as nearly as possible the same words)—*the percentage of A's and a's amongst the offspring can be calculated with the more exactness, the more extensive our knowledge of the corresponding characters in the ancestry*. For instance, one may presumably take it for a fact that the percentage of insane amongst the offspring of the insane is larger than amongst the offspring of normal individuals *i.e.* insanity is inherited. Does the law of "ancestral heredity" hold? If we assume that it does, we are assuming that the percentage of insane amongst the ultimate offspring is greater and greater the more of the ancestry were insane; if we assume on the contrary that it does not, we are supposing that it is completely indifferent whether the ancestry beyond the *immediate* parents were normal healthy individuals or raving lunatics. For the working out of an actual case the reader may be referred to Mr. Galton's paper on the inheritance of colour in Basset-hounds.

It may be as well to point out that the law of ancestral heredity by no means implies that if the characters of all the ancestry are known, the estimate of the character of the offspring becomes an exact determination, That can never be the case, for the offspring of one individual, or of one pair, exhibit a range of variation as a rule only fractionally less than that of the race, although they all have the same ancestry. In point of fact the accuracy of estimate will sensibly, though not rigidly speaking, reach a limit after relatively few of the ancestry (say to the sixth generation or so) are known. Further it should be noted that the law of ancestral heredity is quite distinct from the alleged law of the prepotency of the phylogenetically older character. Apart from the fact that the latter is usually applied to cases of the crossing of distinct races with which the former has nothing to do, and to cases where the relative ages of the characters are measurable by geological time, while the former gives *sensible* weights only to the recent ancestry, the law of ancestral heredity is not a law of prepotency or dominance at all. The whole of a man's ancestry on the female side might be sane; only the last six generations on the male side insane. The law does not state that the offspring will probably be sane, sanity being the phylogenetically older character. Such a statement would be absurd. All that it affirms is that the more of the ancestry are insane, the greater is the chance of insanity appearing in the offspring—a very different thing. I can see no justification whatever for the confusion of the two laws by Mr. Bateson. Professor Weldon, in the *Biometrika* article referred to (January, 1902), states the law of ancestral heredity in these terms, "The degree to which a parental character affects offspring depends not only upon its development in the individual parent, but on its degree of development in the ancestors of that parent." Apart from Professor Weldon's use of the word "affects" which to some extent implies a direct physical influence, and for which I would prefer to substitute some such phrase as "indicates" or "serves as a basis for estimating the character of," this law is, beyond question, as we have seen, of very general application. Yet Mr. Bateson comments on it in the following terms: "Having rehearsed this profession of an older faith Professor Weldon proceeds to stultify it in his very next paragraph. For here he once again reminds us that *Telephone*, the mongrel pea of recent origin, which does not breed true to seed characters, has yet manifested the peculiar power of stamping the recessive characters on its cross-bred offspring, though pure and stable varieties that have exhibited the same characters in a high degree for generations have *not* that power." I quote the passage in full as a characteristic example of Mr. Bateson's method. Mr. Bateson endeavours first, *more suo*, to discredit the statement of the law by referring to it as a "profession of faith," and then remarks that it is "stultified" by another fact with which it has nothing to do. The strength of Mr. Bateson's reasoning is hardly equal to that of his language.

I have, in the preceding passages, used the term "Law of Ancestral Heredity" in a sense somewhat wider than that given by Professor Pearson. Mr. Francis Galton, some years since, put forward a formula, subsequently very considerably modified by Professor Pearson, suggesting or implying certain fixed values for the constants B_1 B_2 B_3, etc. (equation 4) or at least fixed relations between them. This law, Galton's Law, or one of its modifications, has been frequently referred to by Professor Pearson as "*The* Law of Ancestral Heredity." I have ventured to drop that signification, as I do not think the facts indicate any fixity of formula even for intra-racial heredity, a point in which I agree with Mr. Bateson, though all his evidence adduced from hybridisation seems to me quite beside the mark. Being unable to accept Mr. Galton's law as *a* law of heredity, *à fortiori* I cannot accept it as *the* law, and have therefore applied the phrase to a more general statement. Mr. Galton states his law in the form that "the two parents contribute between them on the average one half or 0·5 of the total heritage of the offspring, the four grandparents, one quarter, or $(0{\cdot}5)^2$; the eight great-grandparents, one eighth, or $(0{\cdot}5)^3$ and so on." "The theory" says Mr. Bateson, after some other comments with which I do not deal only on account of their less importance, "further demands—and by the analogy of what we know otherwise not only of animals and plants, but of physical or chemical laws, perhaps this is the most serious assumption of all—that the structure of the gametes shall admit of their being capable of transmitting any character varying from zero to totality with equal ease . . . ." The comment does not hold good at all. Mr. Galton's law is only stated as an average or statistical law, and the "one quarter" contributed by the grandparents *on the average* might be made up by some contributing one half, and others contributing nothing; the average of a series of quantities may exhibit sensible continuity of variation, even though the quantities averaged vary by discrete steps. There is no difficulty for instance in applying the general law of the form (4) to such a case as inheritance of number of petals in flowers, although the coefficients B_1 B_2 B_3, etc. are all fractional; Y only gives the *average* number of petals in the offspring which of course will not be in general a whole number. To the bearing of the analogy of physical and chemical laws I will return later.

A real difficulty in the acceptance of Galton's law as stated in this form lies in the conception of the "heritage," and of ancestry "contributing" thereto, two conceptions of which I find it difficult to grasp the exact meaning. As I know that others have felt a similar difficulty, it may be as well if I point out that the law of regression (the shifting of the offspring from the parental type towards mediocrity) and the law of ancestral heredity are both susceptible of a very simple physical explanation on totally different lines. Both laws, it should be remarked, are known to hold for a sexual reproduction, so that any explanation founded solely on the hypothesis of gamogenesis is necessarily inadequate. I will therefore only consider in this rough indication the first and simplest case. Two assumptions only are necessary. (i.) The continuity of the germ-plasm, or the central idea of that theory, *i.e.* the conception of the soma and germ cells as separate out-growths from the fertilised ovum; the germ cells and soma not being so intimately related that an alteration in any one cell or group of cells in the soma can produce so specific a change in the germ cells that they tend to produce offspring with a corresponding alteration. (ii.) The assumption that the characters—structure or whatever we please to term it—of the germ cell cannot *rigidly* determine the characters of the resulting soma, owing not merely to the variations in definite and assignable external circumstances, but to that residuum of unanalysable variations which we term chance. I do not now propose to justify these assumptions, if they need justification, but merely to point out their consequences. It follows directly from the second assumption that a series of absolutely identical germ cells will not produce a series of absolutely identical individuals, but a group or *array* of individuals differing more or less *inter se*. The somatic character of an individual is not therefore an absolute guide to the character of the ovum from which he sprang nor, *à fortiori*, to the mean character of the germ cells which he produces. If we conceive a number of individuals of the same somatic type, some will be abnormal developments of mediocre germ cells (*i.e.* cells producing on the average mediocre types); others, but these will be fewer, will have sprung from germ cells producing on the average, or usually, more abnormal types. The odds are, therefore, that a given abnormal somatic type is an abnormal development of a mediocre germ cell rather than a mediocre (or subnormal) development of an abnormal cell. But the somatic characters of offspring will follow the germ cell characters and not the somatic characters of the parent; therefore *regression* occurs. Further, as the line of germ plasm is handed on from parent to offspring and the processes of nutrition and growth, if continued unchanged, need not be supposed to alter the *average* character thereof, any one individual in a line is an index to the character of the plasm in that line. Hence if ancestry as well as parents be abnormal it is more probable that the parents are an average development of a really abnormal type of germ cell, and hence more probable that the offspring will follow, and not regress from, the parental type, *i.e.* we have "ancestral heredity."

I have put the whole matter as briefly as possible, without discussing details, because I wish at present simply to emphasise the fact that although the theory of ancestral contributions to a heritage implies the law of ancestral heredity, the converse is not true: the law of ancestral heredity need not in any way imply actual physical contributions of the ancestry to the offspring. The ancestry of an individual may serve as guides to the most probable character of his offspring simply because they serve as indices to the character of his germplasm as distinct from his somatic characters.

The same line of argument applies in the case of attributes. The germ cells cannot in general be treated as if they rigidly determined whether the individual should be an A or an a, the one type of cell merely produces a *majority* of A's, the other a majority of a's—as a loaded die tends to fall the more often on the one face than on the others; only in the extreme case the loading might be so heavy that the die would always rest on the one face. In general then one could not be certain that the germ cells of an A individual (reproducing asexually, to avoid complications) were of the A-type, *i.e.* the type producing a majority of A's; they might be or might not. If, however, the parent of the A-individual were also of the *A*-type, and *à fortiori* if the grandparent were also, and so forth, the germ cells of the *A*-individual would much more certainly be of the type his somatic characters would lead one to expect.

These considerations will, I believe, be useful in considering Mendel's Laws themselves, and their relation to the Law of Ancestral Heredity. I have, I hope, said enough to shew the reader that however the two may be related they cannot at least be "absolutely inconsistent" with each other, as Mr. Bateson contends. The law of ancestral heredity is certainly a law of nature of wide generality which cannot be dismissed in such a fashion. Mendel's Laws I assume to be true also. The problem is to delimit their respective spheres, and shew in what way the one type of law may pass into the other, or the two even coexist.

(to be continued.)

REVIEW.

The Structure and Development of the Stem in the Pteridophyta and Gymnosperms. By E. C. Jeffrey, Ph.D., Phil. Trans. Roy. Soc., B. Vol. 195, pp. 119-146, plates 1-6, 1902.

THE recent appointment of the author of this memoir to a Professorship at Harvard will be welcomed by his friends in this country, though they may feel some regret at the secession from the ranks of British men of science, of so able and energetic a botanist.

In the present communication, Professor Jeffrey completes the Trilogy of memoirs in which he has developed the theory first suggested in preliminary notices, in 1896 and 1897. The Equisetales and the Angiosperms having been already dealt with, the remaining classes of vascular plants (Filicales, Lycopodiales and Gymnosperms) are now considered, and the theoretical conclusions which the author draws from his extensive observations are finally stated.

Professor Jeffrey begins by suggesting a comparison, from the point of view of taxonomic importance, between the osseous skeleton of the higher animals, and the fibro-vascular skeleton of the higher plants. The comparison does not appear to hold very closely, for the vascular system (with which the author's work almost exclusively deals) is, in plants, often quite distinct from the true "skeleton" of mechanical tissue, to which indeed he seldom refers. None the less, the value of characters derived from the vascular system is rightly emphasized. After recognizing the services of palaeobotany in drawing attention to anatomical characters, the author points out that what is now needed is the study of development, by which he understands the gradual elaboration of structure, from the young "seedling" onwards, rather than growing-point development or histogenesis.

Taking the Filicales first, Professor Jeffrey gives a full description of the ontogeny of the vascular system of Marattiaceæ, especially in species of *Danaea*, and finds that it is primitively an amphiphloic fibro-vascular tube (*siphonostele*) interrupted by foliar gaps; here, as in *Pteris aquilina*, the medullary strands are a subsequent development. He observes that the internal phloem appears before the medullary parenchyma "as is commonly the case in young stems of Ferns with the so-called polystelic type of fibro-vascular arrangement" (p. 123). Later work on Marattiaceæ, by Farmer and Hill, and by Brebner, on the whole bears out the author's conclusions, though there seems to be some difference of opinion as to the time of appearance of the internal phloem.

The Osmundaceae hold a critical position in the author's theory. Most obesrvers have regarded the vascular system of these Ferns as a single cylinder, consisting essentially of an intrastelar pith surrounded by a ring of primitively collateral bundles—in fact as belonging to the medullated-monostelic type of Van Tieghem. Professor Jeffrey does not recognize the existence of this type; on his view the pith is an included portion of the fundamental tissue (a return to the original interpretation of De Bary and Sachs) while the collateral bundles have arisen by reduction from concentric strands, such as occur in "polystelic" Ferns, the internal phloem, which they once possessed, having now, for the most part, disappeared. The same explanation is extended to the vascular system of the Gymnosperms and Flowering Plants generally, which he regards as siphonostelic throughout, but modified by the loss of internal phloem. As regards the Osmundaceæ, the evidence for the author's view rests chiefly on *O. cinnamomea*, in which internal phloem normally occurs below each bi-furcation of the stem, and occasionally appears elsewhere. The endodermis in this species may also extend inwards through the foliar gaps, while the pith resembles the cortex in containing brown sclerotic strands; this last character re-appears in *O. regalis* and *Todea superba*, but neither internal phloem nor endodermis occur in any species but *O. cinnamomea*, nor have they in any case been found in the young plant. The author regards the various species as forming a " series of degeneracy," *O. cinnamomea* being the least reduced. In support of his theory of reduced " polystely," Professor Jeffrey brings forward the concentric nature of the foliar bundles and the mesarch structure of those in the stem, but as both these characters appear in protostelic stems (*e.g. Gleichenia, Heterangium*) it is difficult to see how they affect the question. The author's theory of reduction is no doubt a tenable one, but as it receives no support from the development of the young plant, its basis is weak, and many botanists will probably prefer to read the series the opposite way.

The vascular system of the Ophioglossaceæ receives the same interpretation; " evidences of its derivation from an originally concentric stelar tube are, however, not so abundant" (p. 128).

In the case of the Schizaeaceae, Professor Jeffrey agrees with Mr. Boodle as to the facts; he thinks it probable, however, that the medullate type of *Schizaea* has been derived by reduction from the " polystelic" structure of *Mohria* and *Anemia*. This is a difficult question, on which we may hope for new light from further investigations now in progress.

The chief point in the author's remarks on the Gleicheniaceae is his ingenious comparison between the petiolar bundle of certain Gleichenias and the stele of the Osmundaceae. In both cases he finds that the enclosure of ground-tissue within the vascular system is correlated with the disappearance of internal phloem.

The Cyatheaceae show a general agreement with the Marattiaceae; the author's account of the Polypodiaceae, however, contains some new points of great interest. He finds that in a considerable number of these Ferns, *e.g.* various species of *Antrophyum* and *Vittaria*, *Davallia stricta* and *Adiantum pedatum*, the internal phloem and endodermis are wholly or partially lost. In the case of *Antrophyum reticulatum*, the pith at the same time assumes a structure different from that of the cortex, and the type of stele comes to resemble that of a *Botrychium*. These interesting results appear to constitute the strongest part of the author's case; he has here established a strong presumption that the medullated-monostelic type *may* arise by reduction from an amphiphloic siphonostele. This is an important step, but it by no means proves that the theory holds good generally. To take an analogous case; an apparently protostelic structure is known to have arisen in certain cases (*e.g.* water-plants) by reduction, yet no one doubts that in other groups the protostele is really primitive.

The author's treatment of the Lycopodiales is somewhat meagre. The first type described is a highly complicated *Selaginella*, *S. laevigata*, with a tubular amphiphloic stele, and accessory medullary strands, the "ramular gaps" here replacing the leaf-gaps of the Ferns. This species was regarded by Harvey-Gibson as relatively primitive on account of the tubular form of stele, recalling that of many Palaeozoic Lepidodendreae. The resemblance, however, is superficial, for in none of the fossil Lycopods is any tissue present which could be interpreted as internal phloem. On the contrary, the whole of the extensive fossil evidence supports the direct derivation of the medullate stele, so far as it occurs in Lycopods, from protostelic structure, Whatever may be the case with other groups, it would scarcely seem admissible to apply the author's theory of reduction to the Lycopodiales.

We next come to the Gymnosperms, under which head the extinct Cycadofilices are considered. In the genus *Lyginodendron*, of which the anatomy is pretty completely known, the author regards the pith as forming part of the ground-tissue, and, what is more important, believes that the collateral bundles of the stem have arisen by reduction from a system of concentric strands. In support of the former position he states that similar clusters of sclerotic cells occur in both medulla and cortex. In the internodes, however, it is in the *pericycle*, not in the cortex, that they are found, though at the nodes and in the petiole they become cortical. In fact these nests occur in all regions, and have no bearing on the homologies of the tissues. As evidence of reduction from concentric structure Professor Jeffrey relies on "the occasional occurrence of concentric bundles in the stelar tube." It must be pointed out, however, that the inverted wood and bast, which render the bundles "concentric" in these exceptional cases, appear to be entirely of secondary origin; they thus form an example of "anomalous secondary thickening" in the sense of De Bary, and afford no evidence of any variation in the primary structure. It is a pity that this fundamental objection to his interpretation is not dealt with by the author.

The close agreement in structure between *Lyginodendron* and *Heterangium* (a genus somewhat summarily dismissed by our author) points clearly to the direct derivation of the medullated structure of the former from the protostele of the latter type, while the hypothetical intercalation of a concentric, *Medullosa*-like stage, appears gratuitous and unsupported by evidence; no *Medullosa* is known which is in any way intermediate between the types of structure represented by *Heterangium* and *Lyginodendron*.

The comparison drawn by previous writers between the stelar structure of *Osmunda* and that of *Lyginodendron* is accepted by the author, and regarded as supporting his views. He says: "The late Professor Huxley considered that in the almost complete geological sequence from the pentadactyl early horses to the monodactyl horses of the present day, existed one of the strongest proofs in favour of the general principle of evolution by reduction and specialization. We find apparently a similar series of reduction and specialization in the Osmundaceae which may be applied to the elucidation of the general problem of the evolution of the central cylinder in the higher plants" (p. 137). The hypothesis of reduction in the Osmundaceae appears, however, too uncertain at present to be employed with safety in elucidation of the structure of other groups.

In his concluding paragraphs the author sums up the morphological and phylogenetic results of his work. He criticises the views of Strasburger as to the endodermis. That author, as is well known, has drawn a distinction between the "phlœoterma" or innermost layer of the cortex, and the endodermis, a layer characterized by its histological structure, which may or may not happen to coincide with the phlœoterma. Professor Jeffrey appears to treat the two conceptions as identical—wherever he finds a layer of cells with endodermal characters he considers it as fixing the limit between fundamental and vascular tissues. In a physiological sense this, no doubt, holds good very widely; the author, however, makes light of the physiological function of the endodermis (though that it must have *some* function seems obvious). The idea of the morphological value of the endodermis appears to have arisen from the fact of its coinciding, in certain cases (notably in the root) with histogenetic boundaries, and would therefore seem to stand or fall with the doctrine of histogenetic zones, a subject too wide to be entered on here.

Mr. Boodle's view that the pith always forms part of the stele, irrespective of the distribution of the endodermal sheaths, stands in sharp contrast to that of the author, who regards the pith as constantly belonging to the extrastelar ground-tissue. There appears, however, to be no definite point in dispute between the two authors as to the facts of ontogeny, or (so far as this question is concerned) as to the probable course of evolution. The problem is perhaps an insoluble one, the answer depending on the point of view of the observer. Professor Jeffrey regards continuity, demarcation and histological similarity, as sufficient evidence of morphological identity; Mr. Boodle relies rather on corresponding position of the tissues in related forms.

On the other hand the question of reduction from concentric to collateral structure is a real and important one. Either the plants which now possess a "medullated monostele" are derived from ancestors with internal phloem or they are not. In the case of the Polypodiaceæ there is good reason to think that the author's hypothesis is the right one, and that cases of collateral structure in this family have really arisen by reduction. In other groups this is very doubtful, and in some (especially the fossil Lycopods) the evidence is all the other way. The impartial critic will probably take the view that similar vascular structures have originated in different ways on various lines of descent, and that no one rigid scheme can be applied to all. Stages which can be seized "*in flagrante*" (p. 143) are not necessarily stages of degeneracy.

The author's division of Vascular Plants into Lycopsida (Lycopodiales and Equisetales) with ramular, but no foliar gaps in the stelar tube, and Pteropsida (Filicales and Phanerogams) in which foliar gaps are a constant feature, is already familiar to botanists and needs no discussion. The distinction is no doubt a valuable one, and corresponds, in the opinion of the present writer, with natural affinities; the relation of the Equisetal type of stele to that of the Lycopods requires, however, some further elucidation.

The memoir is illustrated by six plates containing numerous figures, all from the author's photographs. The illustrations are of great beauty, though perhaps a little more detail would sometimes have been welcome.

In conclusion, Professor Jeffrey may be warmly congratulated on the completion of a solid and valuable contribution to the morphology of vegetable tissues, which, quite apart from our acceptance or otherwise of his theoretical conclusions, at once places him in the front rank of anatomical botanists.

D. H. S.

A REVISION OF THE CLASSIFICATION OF THE GREEN ALGÆ

BY

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AND

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(*continued from page* 192.)

22. *Sphærozosma.* Corda, 1835.

Cells with a deep equatorial furrow; connected by minute tubercles or cone-shaped processes; elliptical or triangular in end view. Semi-cells oval in side-view. Chromatophore of two diverging plates in each semi-cell.

23. *Streptonema.* Wallich, 1860.

Cells considerably broader than long, with a very deep equatorial furrow; connected by three hyaline cylindrical bands; in end-view 3-armed, each arm with a rounded swollen end. Chromatophore of three diverging plates in each semicell, each plate occupying an arm and branching into two in the swollen end.

24. *Aptogonum.* Ralfs, 1848.

Cells nearly square in side-view, with a very slight equatorial constriction, and a slight terminal concavity; in end-view triangular to quadrangular, or oval. Chromatophore of four to six or eight plates diverging from two, three or four pyrenoids in each semi-cell.

25. *Desmidium.* Agardh, 1824.

Cells oblong in side-view, broader than long, with a slight equatorial constriction; triangular or quadrangular, rarely oval in end-view. Chromatophore in each semi-cell, with as many pyrenoids as there are angles, and two parietal plates diverging from each pyrenoid.

26. *Phymatodocis.* Nordstedt, 1869.

Cells approximately square in side-view, intimately connected by their flat ends; with a very narrow equatorial slit; in end-view 4-armed, with a tubercle on one side of each asymmetrical rounded arm. In side-view, each semi-cell the inverted counterpart of the other.

27. *Didymoprium.* Kützing, 1843.

Cells oval, each with a slight equatorial furrow; connected by their flat ends to form spirally wound threads; in end-view elliptical, with two opposed promontaries, Chromatophore of eight plates diverging from four pyrenoids in each semi-cell.

28. *Gymnozyga.* Ehrenberg, 1840.

Cells barrel-shaped, with a slight equatorial furrow, on each side of which is a ridge; in end-view round, with two opposed projections of the wall; membrane with transverse ridges, and between them, longitudinal striae. Chromatophore of six plates diverging from a pyrenoid in each semi-cell.

29. *Hyalotheca,* Ehrenberg, 1840.

Cells oblong in side-view, intimately connected by their flat ends to form spirally-wound cylindrical threads; equatorial constriction very shallow, with gently sloping sides; in end-view circular. Chromatophore of six to ten plates diverging from a pyrenoid in each semi-cell.

Series II. **Zygnemoideae.**

Plant-body filamentous, attached or free, *consisting of equivalent cylindrical cells* (*only the attachment-cell differs*). *Chromatophores symmetrical with reference to the long axis of the cell,* of three well-marked types, characterising the three families.

Multiplication by fragmentation of the filament.

Reproduction sometimes by the formation of aplanospores (one in each cell), usually by zygotes, which are formed either isogamously in the conjugation canal, or anisogamously in one of the conjugating cells. Parthenogenesis of the gametes sometimes occurs.

Fam. I. SPIROGYRACEÆ.

Chromatophores one to nine in each cell, *each a parietal spirally-wound band with a single row of pyrenoids.*

Genera.

1. *Spirogyra.* Link, 1820.

Chromatophores usually making a considerable angle with the long axis of the cell, rarely parallel with it. Gametes derived directly from ordinary vegetative cells. Conjugation anisogamous.

2. *Sirogonium.* Kützing, 1843.

Chromatophores almost parallel with the long axis of the cell. Gamete-mother-cells formed from vegetative cells by the cutting off a small cell in the case of the functionally female, and of a large, sometimes also of a small, cell in the case of the functionally male. Conjugation anisogamous.

Fam. II. ZYGNEMACEÆ.

Chromatophores two, one placed on each side of the central nucleus, each consisting of a rounded body containing a pyrenoid. Akinetes sometimes formed.

Genera.

1. *Zygnema.* Agardh, 1824.

   Chromatophores with radiating processes. Conjugation isogamous or anisogamous.

2. *Pyxispora.* West and G. S. West, 1897.

   Vegetative cells indistinguishable from *Zygnema.* Conjugation isogamous. Zygote elliptical, with an equatorial ridge bearing a groove, and with its long axis perpendicular to long axis of conjugating filaments.

3. *Pleurodiscus.* Lagerheim, 1895.

   Chromatophores disc-shaped, parietal or somewhat excentric. Cell-sap often purple.

4. *Zygogonium.* Kützing, 1843.

   Chromatophores irregular, sometimes uniting into a single axile body. Cell-sap sometimes purple. Conjugation isogamous.

Fam. III. MOUGEOTIACEÆ.

Chromatophore single, consisting of a longitudinal axile plate with a single row of pyrenoids; sometimes almost divided into two in the middle of the cell. Cells much longer than broad.

Genera.

1. *Mougeotia.* Agardh, 1824.

   Tranverse walls lens-shaped. Part of protoplasm of the conjugating cells not used in the formation of the gametes. Zygote formed in the conjugation-canal, but sometimes extending right across one or both of the two conjugating cells.

2, *Mougeotiopsis.* Palla, 1894.

   Like *Mougeotia,* but pyrenoids absent.

3. *Debarya.* Wittrock, 1872.

   Like *Mougeotia,* but all the protoplasm of the conjugating cells used to form the gametes Zygote formed in the conjugation canal, its brown middle membrane bearing three parallel ridges connected by striae.

4. *Temnogametum.* West and G. S. West, 1897.

   Like *Mougeotia,* but gamete-mother-cells short, specially cut off from vegetative cells.

5. *Gonatonema.* Wittrock, 1878.

Vegetative cells as in *Mougeotia*, but reproduction by increase of vegetative cells to double their original length, division of the chromatophore in the middle, swelling of the cell wall at that point, and finally collection of most of the cell contents in the swelling, which is then cut off as an "aplanospore."

[The cytological details of the process of "aplanospore"-formation in this genus have not been followed, but the sequence of events strongly suggests that the so-called aplanospore is really a zygote, produced by isogamous conjugation of gametes whose mother-cells have never been separated by a wall.]

Class IV.--HETEROKONTAE.

Organisms unicellular, multicellular, or coenocytic. *Cell of "flagellate" or of algal organisation, containing* rarely one, usually many discoid, *parietal, yellow-green chromatophores, devoid of pyrenoids and starch.* The usual anabolite is an oil. The motile individual cells or the *zoospores* are provided *with two flagella* either *unequal in length or opposed in direction,* arising from a spot a little to the side of the anterior end. The motile cells generally exhibit amoeboid or "metabolic" movement.

Series I. **Chloromonadales.**

Organisms, either unicellular and motile or united to form a mucilaginous colony. *Cells of "flagellate" organisation, devoid of typical cell-walls and dividing longitudinally.* Resting cells occur: *gamogenesis does not take place.*

[Though the members of this series must be considered to be Flagellata and not Algæ (see p. 22), it is not possible to omit them from this scheme of classification, since they represent the primitive organisms possessing Heterokontan characters from which the next two series have been evolved.]

Fam. I. CHLORAMOEBACEAE.

Flagellate cells, free-swimming, naked, *with a belt of discoid chromatophores. Flagella very unequal* in length, the short one curved sideways. *Vegetative division* takes place probably *in the motile state.* Resting cells with thick walls occur.

Genus.

Chloramoeba. Bohlin, 1897.

Cells round to ellipsoid, very amoeboid, with one contractile vacuole and two to six chromatophores, usually nourished holophytically, but also capable of living saprophytically in the dark in solutions of sugars, etc., and then devoid of assimilatory pigment.

Fam. II. VACUOLARIACEAE.

Flagellate cells naked *free swimming* and predominantly motile, but *division* takes place only *in the non-motile condition,* within a mucilaginous investment. *Chromatophores numerous. Flagella* two, *approximately equal* in length, but one *directed forwards and* the other *backwards.* Resting cells occur.

Genus.

Vacuolaria. Cienkowski, 1870.

Cells large with numerous parietal chromatophores. The flagella arise in a pit at the anterior end close to which are two contractile vacuoles. A large non-contractile sap-vacuole is often present.

Fam. III. CHLOROSACCACEAE.

Cells predominantly non-motile and united to form a *mucilaginous colony* in which abundant cell-division takes place. In the motile phase (zoospore) the cells have *two lateral chromatophores* and *two unequal flagella* arising close to the apex.

[This family forms a transition from the typically flagellate to the typically algal type, in respect of the dominance of the non-motile condition and the differentiation of a cell-wall.]

Genera.

1. *Chlorosaccus.* Luther, 1898.

Colony a large mucilaginous aggregate formed by repeated quartering of the constituent cells. Cells oval, each with a special wall which is dense towards the surface of the colony and thin or discontinued at the opposite pole. Short flagellum one-third to one-sixth the length of long one.

2. *Chlorobotrys.* Bohlin, 1901.

Cells spherical, 2 (-8) in mucilage. Cell-walls siliceous, but not brittle. Life-history uncertain, neither cell-division nor swarmers yet observed.

Series II. **Confervales.**

Plant-body unicellular, multicellular or coenocytic. *Cells strictly algal in organisation* with several discoid parietal chromatophores. *Reproduction by zoospores with two unequal flagella* (the short one often only demonstrable by special methods); *and by similar iso-planogametes. Aplanospores* occur in most genera.

[Until 1898 the zoospores of genera placed in this series were described as having only one long flagellum, which is the appearance they present when alive or when killed with most reagents. In that year Luther proved that the zoospores of *Conferva* and *Botrydiopsis* possess also a second, short flagellum which had been overlooked because it is generally pressed against the body. This brought the Confervales into line with the Chloromonadales in this most fundamental character as well as in many others, so that their phylogenetic connection seems now indisputable. The zoospores of most of the genera have not yet been re-examined in this matter, but a second short flagellum is assumed to be present in all cases and also in the gametes which were previously described as uniflagellate. Such gametes have been observed in the best known genera, but to some others gametes possessing clearly two flagella of approximately equal length have been attributed; this is, however, not yet established beyond doubt.]

Fam. I. CHLOROTHECIACEAE,

Plant–body unicellular and uninucleate. *Cells* either solitary and *attached* by a basal stalk, *or united by mucilage* to one another to form a small colony. *Reproduction by swarmers* which either germinate singly or conjugate in pairs (*facultative gametes*). The *swarmers* have *one long* conspicuous *flagellum, and presumably a second short one* (not yet demonstrated for any of the genera); and usually *one lateral chromatophore* (two in *Mischococcus*).

Genera.

*Cells solitary and attached by a thick or thin stalk. Vegetative division does not occur.

1. *Peroniella.* Gobi, 1887.

Cells rounded or pyriform, with a single chromatophore; quite imbedded in the mucilaginous investment of other Algæ and attached to the host by a long stalk of extreme fineness. Reproduction by pyriform zoospores which burrow into the mucilage anew and attach themselves by the long flagellum which then becomes the stalk. Gametes not known. Aplanospores occur.

2. *Stipitococcus.* West & G. S. West, 1901.

Chiefly distinguished from *Peroniella* by its much smaller size: should, perhaps, be united with it as a recently described species is not so small.

3. *Characiopsis.* Borzi, 1895.

Cells obovate or round, with several chromatophores; epiphytic by a short thick stalk. Reproduction by division of the cell-contents, either directly to eight zoospores (liberated by solution of the upper part of the mother cell-wall) or to a large number of spherical aplanospores which when liberated, become at once gametangia, each producing two to four gametes. Zygote germinates to form zoospores.

4. *Chlorothecium.* Borzi, 1885.

Cells obovate containing one or a few chromatophores, but otherwise resembling the previous genus. In reproduction the cell-contents divide into a large number of spherical aplanospores (liberated by solution of the middle part of the mother-cell-wall) which at once become zoosporangia liberating two to four swarmers which are facultative gametes. Zygote germinates to form zoospores.

[It seems highly probable that the vegetative cell of *Chlorothecium* will be able to give rise to zoospores *directly* (at all events under certain conditions). If this is so, then the life-histories as well as the morphology of the two previous genera become so similar that no clear *generic* distinction remains between them. Borzi calls the liberated clusters of aplanospores *palmelloid states*, but apparently these never grow or multiply independently.]

** Cells united by mucilage to form colonies. Vegetative division abundant.

5. *Askenasyella.* Schmidle, 1902.

Colony spherical, mucilaginous, free or attached. Cells pyriform, the pointed end directed centrally, and passing into an ill defined stalk, which loses itself in the mucilage. Chromatophore single, and lining the whole of the thin cell-wall except at the pointed end. Each cell may give rise to four to sixteen zoospores which escape by a lateral hole. On germination of the zoospore the long flagellum becomes mucilaginous.

6. *Oodesmus.* Schmidle, 1902.

Colony free-floating, consisting usually of four oval cells united together in one plane by very short thin bands of mucilage. Cell-wall thick; chromatophores one or two. Reproduction by division of the cell-contents into four bodies (uniflagellate zoospores?), which (after very briefly swarming?) unite together (by their flagella ?)

7. *Mischococcus.* Nägeli, 1849.

Cells round with one to four chromatophores; united to form an attached dendroidal cluster by stout tubular mucilaginous stalks, the cells occurring only at the ends of the branches. Reproduction by zoospores, and by gametes. The zygote typically, and the zoospores sometimes, germinate to form a so-called palmelloid state in which the cells are oval, divide in two directions, and have very short broad basal mucilaginous stalks, by means of which all the daughter-cells remain fused together side by side to form a large epiphytic cushion.

Fam. II. CONFERVACEAE.

Plant-body unicellular or filamentous. Cells uninucleate or subcoenocytic. *Reproduction by zoospores with* one long and one short flagellum and with *two lateral chromatophores* (several in *Polychloris*); *also by planogametes,* which in some cases have been described as possessing two equal flagella.

Genera.

1. *Polychloris.* Borzi, 1892.

Cells distinct, spherical or polygonal by compression, with numerous discoid chromatophores; dividing in three directions. Reproduction by zoospores, arising eight to sixteen from a cell, and having each three or more chromatophores.

2. *Botrydiopsis.* Borzi, 1889.

Cell spherical unattached, with a single nucleus and a large number of discoid chromatophores. Vegetative division does not occur. Reproduction by division of cell-contents to form a number of spherical aplanospores or a larger number of zoospores. The zoospores have been proved to possess two lateral chromatophores and two unequal flagella. The aplanospores may become zoosporangia or, after resting, gametangia. The gametes are described as having a single chromatophore and two approximately equal flagella.

3. *Ophiocytium.* Nägeli, 1849.

Cell sub-coenocytic free or attached, cylindrical, straight, or spiral, containing several nuclei and several large parietal chromatophores. No vegetative division occurs. Reproduction by division of the contents to oval aplanospores or to eight zoospores which are liberated by the splitting-off of the upper end of the cell as a lid. In the attached species the lower part of the cell remains as an empty open tube, on the rim of which the zoospores come to rest and develop as a whorl of new tubes. Repetition of this generates a polytomous branch-system of empty tubes. Existence of gametes uncertain.

4. *Conferva.* Lagerheim, 1888.

Cells with one or two nuclei, and several chromatophores; united to form uniseriate filaments. Reproduction by the formation of oval aplanospores or by zoospores (one or two from each cell), provided with one long and one very short flagellum and a number of discoid chromatophores. Zoospores escape by the cells splitting cleanly across at the middle. A long filament may thus split up to a number of so-called H-pieces. The gametes are all alike and of the same appearance as the zoospores, yet they conjugate anisogamously, one coming to rest and rounding up before another swarms up to it and fuses with it.

[The very special structure of the cell-wall common to these two genera unites them closely together. The H-pieces of *Conferva* are made up of a number of apposed layers of pectic compounds, which can be distinguished by staining. The *Ophiocytium* cell is to be regarded as made up of a small homogeneous lid closing a long tube which has the structure of half such an H-piece.]

5. *Bumilleria.* Borzi, 1895.

Closely resembles *Conferva* in life-history and in appearance, but the H-pieces do not apparently possess the same special structure and do not divide the cells sharply into halves. More than two zoospores may arise in one cell. Nature of gametes uncertain.

(*To be concluded.*)

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THE

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EDITORIAL.

THE close of the first year of existence of the New Phytologist offers a convenient opportunity for considering the position of this new venture in botanical journalism.

The organism whose first appearance was made last January is not only still alive, but has great hopes of continuing its existence far into the future. Though its characteristics are at present not quite those which were contemplated at its birth, yet considerable alterations of character are by no means unknown in the early life-history of living beings of all kinds, and if circumstances have to some extent forced this particular individual out of the most desirable path, a change in the direction of the type on which it was originally planned is still possible.

The Editor much regrets the almost complete absence of Notes on Recent Literature and other subjects of current botanical interest, especially during the latter part of the year. Contributors of these have, so far, not been forthcoming, and it is impossible for the Editor himself to undertake more than a very small portion of such work. Nevertheless it is felt that this feature should be an integral part of the New Phytologist, if the journal is not to become a mere collection of short papers. A systematic attempt will be made to secure a series of such Notes for the new volume, but the Editor desires to impress upon all those who take an interest in the welfare of the journal (and he is glad to believe that their number is not small) the great service they would be doing it by occasionally contributing matter of this kind.

Correspondence, also, has for the most part been conspicuous by its absence; and this again the Editor regrets, believing that a freer discussion of the innumerable points that arise in connexion with botanical work of all sorts, would be of great benefit to every one concerned. A fear which had been expressed in more than one quarter that this journal might become a "cockpit" of botanical controversy has certainly not been realised. The botanists of this country have shewed no tendency whatever to excessive combativeness, and it may well be doubted whether a little less reticence would not prove stimulating; it would certainly give a greater liveliness to the pages of the New Phytologist.

In spite of these shortcomings the reception accorded to the journal during the first year of its existence has been distinctly encouraging, and the Editor has every reason to congratulate himself on the quality of the original papers and reviews which he has received.

A further increase in the number of subscribers and a regular supply of notes and correspondence would enable the journal to be enlarged, and, while retaining its present satisfactory features, to acquire a better balance between matter of different kinds.

To all the contributors during the past year, as well as to the subscribers, the Editor desires to offer his very hearty thanks for their support, and he trusts that as a result of the present appeal the New Phytologist may be enabled to increase its usefulness and establish itself on a firmer basis.

MENDEL'S LAWS AND THEIR PROBABLE RELATIONS TO INTRA-RACIAL HEREDITY.

By G. Udny Yule.

(Continued from page 207.)

On passing from the Law of Ancestral Heredity to Mendel's Laws, we are passing from a law of intra-racial individual heredity to a series of laws based solely on hybridisation-experiments, and clearly stated by their discoverer as laws of hybridisation only. The experimental plants must, Mendel states (I quote from Mr. Bateson's translation, "Mendel's Principles" p. 42) "possess constant differentiating characters." After trying thirty-four varieties of peas he found that while one exhibited some aberrant individuals, "all the other varieties yielded perfectly constant and similar offspring; at any rate, no essential difference was observed during two trial years." The thirty-three "constant" varieties being obtained "for fertilisation, twenty-two of these were selected and cultivated during the whole period of the experiments. They remained constant without any exception." The races for crossing were thus chosen with the greatest care and patience so as to be absolutely distinct; an A individual mated with an A never producing a's, nor vice-versâ, for, as I understand, the whole period of ten years (two years of preliminary trials and eight years of experiment.)

Mendel's observations, as most of the readers of these articles will be aware, revealed several distinct uniformities, the verbal description of any one of which might be legitimately entitled a "Mendel's Law." When the two parent races A and a were crossed, their mongrel or hybrid offspring resembled uniformly either the A's or the a's—say the former, in which case A was termed the dominant character, a the recessive. When these first uniform hybrids were crossed *inter se*, the resulting offspring were no longer uniform but broke up again into two classes resembling the parent races—approximately three-fourths exhibiting the dominant character and one-fourth the recessive. The whole of these "extracted" recessives—to use Mr. Bateson's convenient terminology—breed pure, *i.e.* never give rise again to the dominant form. Of the dominants, however, only one-third breed pure, the remainder giving rise again to dominants and recessives in the proportion of three to one. These remarkable results Mendel explained by a hypothesis which certainly appears, for the case of a *single* character, of most attractive simplicity. He supposed that a sorting process takes place during the formation of the germ cells of the Aa hybrids, of such a nature that each finally formed gamete, without exception, only contains the germinal representative of either the A-character or the a-character, and that conjugation between A-gametes and a-gametes takes place at random. The result is that the zygotes AA, Aa, aA, and aa are all formed with equal frequency. But the heterozygotes (to use Mr. Bateson's terminology again) both give rise to individuals resembling the pure dominant form. The offspring therefore exhibit three dominant forms (one pure and two hybrids) to one recessive (necessarily pure).

This law of disjunction, or "segregation," Mendel tested also for pairs and triplets of characters. The results obtained for one character alone leave it open to question whether the group of characters (represented by the germ-plasm, chromatin or whatever it may be) derived from the one parent, has separated bodily from that derived from the other, or whether any more complex process has taken place. The latter Mendel found to be the case; two races, *ABC* and *abc* being crossed, and the hybrids bred *inter se*, the resulting offspring exhibited not merely the parent forms but all the eight possible combinations of somatic characters—*ABC*, *aBC*, *AbC*, *ABc*, *abC*, *aBc*, *Abc*, and *abc*, some being pure and some hybrid forms, as before. These re-combinations of characters and the approximate proportions in which they occurred Mendel held to indicate that each somatic character observed has some distinct and separable germinal representative—"Anlage," determinant or physiological unit, as we might term it—and that the formative divisions of the germ cells always take place in such a way that the finally formed gametes are homogeneous with respect to each character of a pair—no cell containing any *pair* of determinants like *Aa* or *Bb*—but otherwise at random. He experimented on one pair of characters in *Pisum*, form of seed (round or angular) with cotyledon-colour (yellow or green), and on one triplet, seed-coat colour (grey-brown or white) in addition to the above, and the law held in both cases with reasonable accuracy. Mr. Bateson and Miss Saunders give in the *Report* particulars of a few experiments on pairs of characters, *viz.*, colour of flower (violet or white) with character of fruit (smooth or prickly) in *Datura*, character of comb (rose or single) with extra toe in crosses of Leghorn with Dorking fowls, and colour of plumage with form of comb (pea or single) in crosses of Leghorns with Indian Game Fowls. The numerical proportions obtained by the experimenters in these cases diverge more or less (most notably in the second case) from those to be expected on Mendel's hypothesis, but there is no denying the re-combinations of characters that have taken place; starting for instance with breeds of poultry exhibiting rose comb with extra toe and single comb without extra toe, respectively, two new breeds were obtained exhibiting *single* comb with extra toe and *rose* comb without.

Mendel's hypothesis is so ingenious and remarkable, and possibly of such far-reaching importance, that one can understand Mr. Bateson speaking of it as the "essential part" of his discovery, to the complete exclusion of the law of dominance and the various laws of numerical proportions which summarised the *facts* observed. These last two laws obviously enough do not hold in many cases. If they are excluded as not "essential," the "top-hamper," to use Mr. Bateson's nautical metaphor applied to another matter, "is cut down and the vessel altogether more manageable; indeed she looks trimmed for most weathers."

These then are the facts and the hypothesis the relations of which to the phenomena of intra-racial heredity have to be considered and discussed. The first question to be asked in such a discussion, is one that does not seem to have occurred to any of Mendel's followers, *viz.:* what, exactly, happens if the two races *A* and *a* are left to themselves to inter-cross freely *as if they were one race?* It must be remembered that it is only the knowledge given by preliminary trials like those carried out by Mendel which enables us to state that the races *are* distinct; a man who was merely given a sample of seed from the dominant forms occurring after hybridisation had taken place, would conclude that they were not so—he would find that *A*'s crossed *inter se* gave rise to some *a*'s, though not indeed the reverse, and would therefore class the two forms as springing from the same stock. Now when *A*'s and *a*'s are first inter-crossed we get the series of *uniform* hybrids; when these are inter-bred we get the series of three dominant forms (two hybrids, one pure) to one recessive. If all these are again intercrossed at random the composition remains unaltered. "Dominant" and "recessive" gametes are equally frequent, and consequently conjugation of a "dominant" gamete will take place with a "recessive" as frequently as with another "dominant" gamete. Consider then the successive generations of posterity of the dominant forms, starting, say, with 300 of which 100 are pure. The 100 pure individuals will give rise to dominant forms in the proportion of 50 pure to 50 hybrids; the 200 hybrids may, as segregation takes place, be considered as 100 pure dominants and 100 pure recessives, the former giving rise to 50 pure dominants and 50 hybrids, the latter to 50 hybrid dominants and 50 *pure recessives.* The 300 parent dominants, therefore, give rise to offspring in the proportion of 250 dominant forms to 50 recessive, *i.e.*, the chance of a dominant parent producing a dominant form as offspring is $\frac{5}{6}$. Now consider these 250 dominants whose parents were dominants also, 100 of them being pure and 150 hybrids. The 100 pure dominants will give rise as before to 50 pure and 50 hybrid forms, the 150 hybrid forms to pure dominants, hybrid dominants and pure recessives in the proportion of 37·5 : 75 : 37·5. Five hundred dominants whose parents were dominants should therefore produce 425 dominant offspring to 75 recessives, *i.e.*, the chance of their producing a dominant form would be $\frac{425}{500} = \frac{17}{20} = \frac{51}{60}$ while the chance of a dominant of unknown parentage producing a dominant form is only $\frac{50}{60}$. But this is precisely a case of the law of ancestral heredity! It is not difficult to continue the calculations on the same simple lines, but the work may be abbreviated by the following considerations. Let T_n denote the total number of dominants in the *n*th generation all of whose ancestors in one line are also dominants, and let p_n of the T_n be pure, i_n impure or hybrids. Then quite generally one-half of the pure dominants and one-quarter of the hybrids of any generation give rise to pure dominants as offspring, while the remaining half of the pure dominants and one-half of the impure give rise to hybrid forms. That is in symbols

$$p_{n+1} = \tfrac{1}{2}\,p_n + \tfrac{1}{4}\,i_n \qquad (5)$$

$$i_{n+1} = \tfrac{1}{2}\,p_n + \tfrac{1}{2}\,i_n = \tfrac{1}{2}\,T_n \qquad (6)$$

Adding the two equations together

$$T_{n+1} = T_n - \tfrac{1}{4}\,i_n \qquad (7)$$

or by equation (6)

$$T_{n+1} = T_n - \tfrac{1}{8}\,T_{n-1} \qquad (8)$$

Dividing out on both sides of this equation by T_n and writing

$$C_n = \frac{T_{n+1}}{T_n} \qquad (9)$$

where C_n is the chance of a dominant form of the *n*th generation producing dominant offspring, we have finally

$$C_n = 1 - \frac{1}{8\,C_{n-1}} \qquad (10)$$

an equation which enables us to calculate the remaining chances very easily, given that $C_1 = \frac{5}{6}$. I find

$C_1 = {\cdot}83333$
$C_2 = {\cdot}85000$
$C_3 = {\cdot}85294$
$C_4 = {\cdot}85345$
$C_5 = {\cdot}85354$

where, as is found by equating C_n to C_{n-1} in equation (10) C tends towards the limiting value ·85355339 . . . The figures illustrate as nicely as could be desired the two chief properties of Ancestral Heredity—(i.) the chance of an *A* producing an *A* is increased if the ancestry be also *A*'s. (ii.) it is not of much use to take into account more than the first few generations of ancestry (cf. p. 203 supra), for the chance C rapidly approaches a limiting value.

Mendel's Laws, so far from being in any way inconsistent with the

Law of Ancestral Heredity, lead then directly to a special case of that law, for the *dominant* attribute at least. For the *recessive* attribute it does not hold, the chance of a recessive producing a recessive offspring is, on the above hypothesis of random mating, one-half, whatever the parentage may be. Nor is it difficult to see why the law applies in the former case. *Ex hypothesi* pure dominant and hybrid zygotes produce dominant forms indistinguishable the one from the other, so that the somatic characters of the individual are not an absolute guide to the character of his germ cells—they may or may not be of the pure dominant type even though his soma be of the dominant form. If, however, the parent, grandparent, etc., be of the dominant form also, the absence of recessive individuals in the ancestry gives a stronger and stronger presumption that the germ cells are of the type which the somatic characters of the individual would lead one to expect. It is equally easy to see why the law does *not* hold in the case of the recessive attribute. *Ex hypothesi* again, recessive forms can only be produced by pure recessive germ zygotes; it is therefore *certain* without any further witness that the germ cells produced by recessive individuals must be themselves recessive—knowledge of the ancestry is useless for predicting the nature of the germ cells of such an individual, and therefore equally useless for predicting the nature of his offspring. Mendel's Laws, in implying "that the cross-breeding of parents *need* not diminish the purity of their germ cells or consequently the purity of their offspring" (Mendel's Principles, p. 114), do *not* assert, as stated by Mr. Bateson, "a proposition absolutely at variance with all the laws of ancestral heredity *however formulated*" (my italics). Purity of germ cells may very well subsist for a proportion of the individuals of a race without in any way invalidating the principle of the Law of Ancestral Heredity, in the sense defined; it is a law applying to aggregates and predicates nothing concerning the individual. The value of the work of Mendel and his successors lies not in discovering a phenomenon inconsistent with that law, but in shewing that a process, consistent with it, though neither suggested nor postulated by it, might actually occur.

The form of the law of ancestral heredity to which Mendel's principles have led us is, however, clearly a special case, and the next question to be asked is therefore this :—in what way may the special conditions under which Mendel's Laws hold good be broadened so as to permit of a generalisation of the results? Two of these conditions suggest themselves at once as being in all probability somewhat exceptional in character, *viz :* (i.) the necessity for *dominance*, or, to define it in a somewhat more general sense than that used by Mendel, the condition that the hybrid zygote Aa should always behave, as regards the production of the attribute noted, as if it were a pure zygote of the one race, say A ; (ii.) the necessity for the given somatic attributes being rigidly *predetermined* by the characters of the gametes, and not liable to such fluctuations owing to the variations of circumstance or otherwise that an individual of the pure race A might be classed as an a or vice versâ. As pointed out already (p. 206) this condition cannot universally hold good. To take an example from the inheritance of disease, the chances of an individual dying of phthisis depends not only on the phthisical character of his ancestry, but also very largely on his habits, nurture, and occupation. If, however, either dominance fail, or the rigid predetermination of the somatic attributes by the germ cell, or both, Mendel's Laws will cease to hold, but the Law of Ancestral Heredity will still apply.

Suppose first that dominance fails, and, to take a rather interesting case, suppose the failure to be complete, *i.e.* assume the heterozygotes on development exhibit A characters and a-characters with equal frequency. Then when the two forms are first crossed the resulting offspring, hybrid without exception, will exhibit both attributes with equal frequency. When these hybrids are crossed *inter se*, the offspring will again exhibit both characters with equal frequency, but one-half of both forms will be pure, the other half hybrids. All succeeding generations after this will be the same.

Consider then the offspring of say 400 A's. Mating being random, as before, conjugations of an A-gamete with an A-gamete and with an a-gamete will be equally frequent. Of the 200 pure A's, 100 mate with A's and produce 100 pure A's; 100 mate with a's and produce 50 hybrid A's and 50 hybrid a's. The two hundred hybrid A's may be treated separately as 100 pure A's and 100 pure a's. The former give rise to 50 pure A's, 25 hybrid A's and 25 hybrid a's, the latter to 25 hybrid A's, 25 hybrid a's and 50 pure a's. Adding up, the four hundred A's give rise on the whole to 250 A-forms (150 pure, 100 hybrid), and 150 a-forms (100 hybrids, 50 pure). The chance of an A producing an A is therefore $\frac{250}{400} = \frac{5}{8}$. The chances of an A whose parent, parent and grand-parent, and so on are A's producing an A-form as offspring are most easily calculated by the method of equations (5) — (10). To use the symbols of those equations let T_n denote the total number of A-individuals of the nth generation, all of whose ancestors in one line are also A's, and let p_n of these be pure, i_n impure. Then we have in the present case:—

$$p_{n+1} = \tfrac{1}{2} p_n + \tfrac{1}{4} i_n \tag{11}$$

$$i_{n+1} = \tfrac{1}{4} p_n + \tfrac{1}{4} i_n = \tfrac{1}{4} T_n \tag{12}$$

whence, as before, if C_n be the chance of an *A*-individual, all of whose *n* ancestors in one line are *A*'s, producing an *A*-form as offspring

$$C_n = \frac{3}{4} - \frac{1}{16 . C_{n \times 1}} \tag{13}$$

This equation gives the following figures for the successive chances :—

C_1 = ·62500
C_2 = ·65000
C_3 = ·65385
C_4 = ·65441
C_5 = ·65449

where again the value of C tends towards a fixed limit ·6545085 . . . obtained by writing C_n for C_{n-1} in equation (13) and solving. As we have assumed the complete absence of dominance in the above case, the values of C given will apply to both *a*'s and *A*'s. Had we assumed only a partial failure of dominance, supposing, *e.g.* the heterozygote to give rise to 80% of *A*'s and 20% of *a*'s, the law of ancestral heredity would still have applied to both forms, but the two series of chances would have been different. The failure of dominance thus generalises the forms of the law of ancestral heredity derivable from Mendel's principles in two different ways (i.) by rendering it possible to obtain any arbitrary value for C_1, (ii.) by rendering the law applicable to *a*'s as well as *A*'s.

I have, of course, in the preceding, assumed random mating merely to simplify the work. If the mating were homogamic, *A*'s only mating with *A*'s, and *a*'s with *a*'s, as would generally be the case if the breeder wished to obtain as nearly as possible pure races of *A*'s and *a*'s, the law of ancestral heredity would still apply. The working would, however, be a good deal complicated, for the proportion of pure forms and hybrids amongst the *A*'s would vary from one generation to the next.

Next suppose the absolute predetermination of the somatic attributes by the germ-cell to fail, pure zygotes of the one type producing not only *A*'s, but also a proportion of *a*'s, and pure zygotes of the other type, not only *a*'s, but also a proportion of *A*'s. At the same time, to keep the case fairly simple, let dominance in a generalised form still hold good, the heterozygote behaving, as regards the proportions of the two forms produced, precisely as if it were a pure homozygote of one or other type. Let the two classes of gametes be, say, *B*'s and *b*'s, pure *B*-zygotes producing 70% of

A's, pure *b*-zygotes 35% of *A*'s, and let the *B*-gamete be dominant over the *b*-gamete in the sense that the *Bb* zygote produces 70% of *A*'s just as if it were a pure *BB*-zygote. Now, the assumption of the break-down of "predetermination" brings in a new element; we have not only to consider *A*'s developed from the dominant *BB*-zygotes and hybrid *A*'s developed from the heterozygotes but also *A*'s that have developed *from the pure recessive bb-zygotes*, "aberrant recessives" as they may be termed. In assuming the race, as before, to have reached the steady state, in the second generation after the first cross there will again be pure *B*'s, *Bb*-heterozygotes and pure *b*'s in the proportion of 1: 2: 1. But the pure *B*'s and the *Bb*-zygotes both develope 70°/₀ of *A*-forms and 30°/₀ of *a*'s; the *b*'s develope 35°/₀ of *A*-forms and 65°/₀ of *a*'s; therefore the proportion of *A*-forms in the race will be

$$\frac{3 \times 70 + 35}{4} = \frac{245}{4} = 61{\cdot}25\,{}^{\circ}\!/_{\circ}$$

while of these A forms $\frac{70}{245}$ or 28·57°/₀ are pure, $\frac{140}{245}$ or 57·14°/₀ hybrids, and $\frac{35}{245}$ or 14·29°/₀ aberrant recessives. As before, let T_n be the whole number of dominant forms, all of whose ancestors in one line are also dominants, in any one generation, and of these let p_n be pure forms, i_n impure or hybrids, and e_n aberrant recessives. Then I find that the following relations, corresponding to (11) and (12), or (5) and (6) hold good:—

$$p_{n+1} = {\cdot}35\, p_n + {\cdot}175\, i_n \tag{14}$$

$$i_{n+1} = {\cdot}35\, p_n + {\cdot}35\, i_n + {\cdot}35\, e_n \tag{15}$$

$$e_{n+1} = {\cdot}0875\, i_n + {\cdot}175\, e_n \tag{16}$$

where of course

$$T_n = p_n + i_n + e_n \tag{17}$$

These equations do not appear to give readily an expression relating the chance C_n to C_{n-1} as in equations (10) and (13), the aberrant recessives forming a troublesome element, but they enable the values of T_2, T_3, etc. to be calculated directly from the figures given above, say $T_1 = 245$, $p_1 = 70$, $i_1 = 140$, $e_1 = 35$ (the absolute figures do not matter). Then C_n is given at once by the ratio of T_{n+1} to T_n. Using this process I find

$$C_1 = {\cdot}62500$$

$$C_2 = {\cdot}63000$$

$$C_3 = {\cdot}63194$$

$$C_4 = {\cdot}63269$$

$$C_5 = {\cdot}63298$$

The figures were deliberately chosen so as to make the value of C_1, the same as in the last case, *but the values of the remaining chances are totally different.* The differences between successive chances run as follows in the two series—

Failure of dominance.	Failure of predetermination.
·02500	·00500
·00385	·00194
·00056	·00075
·00008	·00029

In the first case the knowledge of the grand-parent makes a marked difference in the expectation as to the attributes of the offspring, but the higher ancestry are of very rapidly diminishing importance; in the second case the difference introduced by the knowledge of the grand-parent is small, but the higher ancestry are of greater relative importance. Moreover one could find a whole series of pairs of values for the proportions of A's contributed by B-cells and b-cells (instead of ·7 and ·3), such that the chance of an A of unknown parentage producing an A-form as offspring was 0·625, but for each of these pairs the remainder of the series of chances would be different. This is a greater generalisation than could be obtained by the former assumption of the failure of dominance alone. Given that the heterozygotes produce any fixed proportion of A's, whether 100, 80, 60 or 50 $^0/_0$, the *whole* of the series of ancestral chances is, in that case, determined, so that no two different series can be obtained starting from the same value.

The preceding considerations should suggest to the "Mendelian" that it is a little futile to deny the fact of ancestral heredity when its existence is predicated by his own results, and to the biometrical school that they on their side should be rather cautious in drawing conclusions as to the processes that are or are not consistent with, and still more implied by, the existence of that phenomenon. I gave on pp. 205-6 supra, one theory accounting for the occurrence of ancestral heredity, *viz.:* the failure of "predetermination," and may confess that I had not then remarked that the application of Mendel's Laws, without any modification, would lead to the same result; both theories implying—and this seems the one thing needful—the development of *similar* somatic characters from germ cells of *different* characters. *One* case of ancestral heredity arises directly from Mendel's Laws, and a whole series of cases of a very general character indeed may be derived by supposing either dominance or predetermination of the somatic attributes to fail; the case of *both* failing would be more general still. In any case then where it is only possible to deal with *attributes*, and not measurably variable characters, it seems impossible to disprove the existence of segregation; it may occur (as Mr. Bateson seems to consider probable) or may not. Nor have we exhausted the ways in which segregation may be masked, apart from any question of its partial failure such as might be invoked to account for some of the divergent results obtained by Mr. Bateson and others. In supposing dominance to fail, we have still assumed the inheritance to be exclusive; this is a logical necessity if predetermination hold, but, if predetermination fail, as well as dominance, the inheritance may become *blended*, *i.e.* the heterozygote may produce, on the average, a per-centage of A's characteristic neither of the B-cells nor the b-cells (in our previous notation), but intermediate between the two; such blending would give rise to yet another series of forms of ancestral heredity.

So far, however, we have dealt solely with cases of inheritance of attributes, without considering the individual variations to which the attribute may be subject within the race; but the relation of these individual variations and their laws of inheritance to the phenomena considered by Mendel is obviously a question of first-class importance. They present two features not directly treated by Mendel at all, but noticed at some length by Mr. Bateson—a sensible continuity of variation in the first place, and, so far as our experience goes, *blended* inheritance in the second, the offspring of two widely different parental forms shewing no tendency to revert to such forms, but resembling the offspring of an intermediate type.

There can be no doubt, of course, as to the *existence* of such individual variations in many of the characters dealt with by Mendel and his followers—length of stem in peas may be cited as an instance where the variations are not merely conspicuous, and, one would imagine, susceptible of easy quantitative measurement—but they are necessarily neglected by hybridisers, who unfortunately rely on their unaided judgments (no sarcasm is intended). The attitude of Mr. Bateson towards these individual variations, and his views on the bearings of Mendelian phenomena on the conceptions of variation in general are rather difficult to follow. He believes, as I gather, that the origin of races or of species is due solely to large and marked variations, and that small variations are of no importance, and speaks of Mendel's discovery as "that discovery which, once and for all, ratifies and consolidates the conception of discontinous variation" (Mendel's Principles, p. 116). It is not easy to see in what way. As he states elsewhere (*Report*, p. 150) "Mendel's discovery.... applies only to the manner of transmission of a character already existing. It makes no suggestion as to the manner in which such a character came into existence," and the question of the origin of varieties stands, therefore, precisely where it did. Mendel's work has only ratified the conclusion of the biometric school, that, beyond question, large variations are rare, for as we have already pointed out, Mendel's Laws cannot hold in any case where *A*'s give rise to *a*'s during the course of the experiments, and Mendel himself states that no such large variations were remarked in thirty-three varieties of peas during ten years. I do not wish to imply that such variations do not occur at all—on the contrary I think that, *e.g.*, the chemical properties of the soma necessarily imply discontinuity of variation in some respects, a discontinuous origin of colour varieties such as those of the Iceland Poppy *(Papaver nudicaule)* being highly probable—but all the evidence we have goes to indicate that large and sudden variations are most exceptional, the highly divergent individuals forming a vanishingly small proportion of any race.

Mr. Bateson reaches his conclusion as to the importance of Mendelian phenomena for the theory of discontinous variation only, I fancy, by tacitly assuming that the germinal determinant of a character is a structure—or whatever one may term it—incapable of small variations, and as fixed and stable as the ideal molecule of a chemical compound; this I take to be the meaning of his reference "to physical and chemical laws," as rendering continuous variation in the germ cell improbable (p. 22), in the sentence already quoted from Mendel's Principles But this assumption is in no way justified by the results of Mendel's work; all that is predicated by his hypothesis is the existence of some sort of separable determinant for each character for which the law of segregation holds; concerning the variability of that determinant nothing is postulated but the fact that it shall not be so large as to render the boundary between the two races obscure. Surely the very fact that the germplasm gives rise to a long and complex ontogeny indicates that its molecules differ in some way from the simple molecules of water, salt, or sulphuric acid? A dozen or two of atoms may be susceptible of only a few stable groupings, but can the same assumption be made as regards a molecule built up of some thousands? Richter's *Lexikon der organischen Verbindungen* gives for instance as the formula for Haemocyanin C_{867} H_{1363} O_{258} N_{223} S_4 Cu for Haemoglobin, C_{758} H_{1203} O_{218} N_{195} S_3 Fe, the first containing 2716 atoms, the second 2378. I confess I speak without a knowledge of modern chemistry, but I can see no physical reason why the loss of an atom or two of hydrogen, or of carbon, in any such case should entail so great an alteration of structure in the molecule as to *alter completely* its physical and chemical characters. It does not seem wholly absurd to suggest that one might obtain *within limits* a sensibly continuous variation of properties with such a compound, even supposing it possible to isolate "pure cultures" of identically similar molecules. "Continuous variation" would then correspond to such minor alterations as did not destroy the stability of the general structure, "discontinuous" or abnormally large variations to such alterations as caused the whole structure to slide over, so to speak, into a new position of equilibrium. I write with a picture in my mind of Mr. Galton's model:—an irregularly polygonal prism which is stable about its position of rest on one face for small oscillations, but will fall into a fresh position if the oscillation be too great (Bibliography, 2). So far then as speculative possibilities go, the occurrence of *sensibly* continuous variation in the properties of an isolated "determinant" seems a hypothesis by no means to be excluded, and surely it can be put to the test. Mr. Bateson appears to accept, and Mendel's hypothesis almost to imply, the truth of the theory of the continuity of the germ plasm as distinct from a theory of pangenesis. If then the individual variations of a character are heritable, it follows that they are, in part at least, due to germinal variation and not wholly to circumstance; if the character is one obeying Mendel's Laws, it also follows, with a high degree of probability, that it is represented by a single determinant, and therefore if the individual variations are heritable, variations in the single determinant are possible. Such an experiment is surely necessary to clear up the facts.

But further, *all* characters cannot be simple units. To take the simplest possible case of compounding, let x_1 x'_1 be a pair of corresponding lengths (say) in two races, these lengths obeying the laws of dominance and segregation; and let x_2 x'_2 be another pair pair of corresponding lengths also obeying the laws. Then clearly Mendel's Laws cannot hold for the "compound characters"

$$X = x_1 + x_2$$
$$X' = x'_1 + x'_2$$

If x_1 and x_2 be both dominant with respect to x'_1 and x'_2 then the first generation of offspring will exhibit X as the dominant character; but if x_1 and x'_2 or x_2 and x'_1 are the dominant forms then the first generation may exhibit a character that is a "blend" or intermediate between the two parent races, or a character greater or less than either. In the second generation again the parental forms will not be the only ones to appear; the new forms $x_1 + x'_2$ and $x'_1 + x_2$ will also present themselves. Two doubly-compound characters will therefore give rise after crossing to *four* somatic forms; two triply-compound characters to *eight*; two characters compounded of n such units to 2^n forms. But how great is n likely to be in such a case as *stature*, assuming that it *can* be analysed into a set of Mendelian units? As Mr. Galton has remarked ((2) p. 83) "... human stature is not a simple element, but a sum of the accumulated lengths or thicknesses of more than a hundred bodily parts, each so distinct from the rest as to have earned a name by which it can be specified. The list includes about fifty separate bones, situated in the skull, the spine, the pelvis, the two legs, and in the two ankles and feet." Surely it would be a very moderate estimate that the number of units could not be less than 50? Yet this would suffice to give, on the simplest Mendelian assumption that each unit can only exhibit two types, not some mere ten thousand different values of stature, the run of which would be quite indistinguishable from strictly continuous variation, but *over a thousand-million million different types!* Even then if the variations of "units" do take place by discrete steps *only* (which is unproven), discontinuous variation must merge insensibly into continuous variation simply owing to the compound nature of the majority of characters with which one deals. There does not seem any escape from this conclusion. Continuous variation, in the present state of our knowledge, we can only say *may* be due to continuous variation of the elements of the germ cell (determinants or what not), or may be due to the compounding in some way of the discontinuous variations of a number of such elements.

Precisely similar considerations hold good for the case of blending. It is quite possible that characters behaving in other respects as Mendel's Laws would lead one to expect *i.e.*, "unit characters," may in some cases give a blended form for the individuals developed from the heterozygote. But in any case compound characters must blend—more or less. This is obvious if dominance be absent; two pure forms $x_1 + x_2$ and $x'_1 + x'_2$ would then produce with equal frequency offspring of the somatic types $x_1 + x_2$,

$x_1 + x'_2$, $x'_1 + x_2$, $x'_1 + x'_2$, the mean of which is precisely $\frac{1}{2}(x_1 + x'_1 + x_2 + x'_2)$ *i.e.* the mean of the two parent forms. If dominance still hold good the result is not quite so obvious, but it seems correct to state that so long as the greater and the lesser values of the pairs like $x_1\ x'_1$ are the dominants with about equal frequency, the inheritance will be blended, while otherwise blends will only occur in a proportion of the results.

This possible mode of the occurrence of blending was noted long ago by Mr. Galton. He found that the inheritance of stature was strictly blended, as tested by the fact that the offspring of a tall mother with a short father, or *vice versâ*, shewed no more divergence *inter se* than the offspring of two mediocre parents. The inheritance of eye-colour on the other hand he found to be *exclusive*, the offspring generally resembling the one parent or the other, and intermediate tints being rare. "The blending in Stature," he remarks (2, p. 139) "is due to its being the aggregate of the quasi-independent inheritances of many separate parts, while Eye-colour appears to be much less various in its origin." Blending then *must* occur with compound characters, it *may* occur for all we know in some cases of unit characters. It would be easier to gauge the probabilities, if Mendel's followers had made some experiments with a view to elucidating the nature of "exclusive" inheritance in general, and of the very curious phenomenon of "dominance" in particular.

I must apologise for the length to which these remarks have extended, but the subject is a large one, and even as it is I have been compelled to pass over many subsidiary points. It is, however, essential, if progress is to be made, that biologists—statistical or otherwise—should recognise that Mendel's Laws and the Law of Ancestral Heredity are not necessarily contradictory statements, one or other of which must be mythical in character, but are perfectly consistent the one with the other and may quite well form parts of one homogeneous theory of heredity. To make my own position clear, let me repeat with regret, that I cannot include under the same heading the special laws as to the operation of Ancestral Heredity which were formulated by Galton and Pearson. These laws have, beyond question, been of service in suggesting lines of research and possible methods of study, but the *fixity* of the numerical constants involved, which they imply, has not stood the test of time. Selective mating, natural selection, reproductive selection, the effect of circumstance, had all in turn to be recognised as causes affecting the values of the constants of heredity, until now any statement as to numerical fixity seems reduced to the truism that the constants will always be the same unless for some reason they are different. What is required from a physical theory of heredity is that it should assign a meaning to the variations in the constants that do occur, enabling one, given the law of ancestral heredity for an organ, to state the relative influences thereon of the different agencies concerned—selection, in all forms, circumstance, and so forth. That an ideally complete theory cannot come yet, may be conceded at once; that it is impossible in the present state of biology to form a quantitative theory, founded on clear and definite physical conceptions, which will carry one some steps on the way, I do not believe.

BIBLIOGRAPHY.

In the preceding articles I have only given definite references to the two volumes mentioned in the first note: the following list includes all those that are necessary for the points referred to as regards the Law of Ancestral Heredity, etc.

(1) Francis Galton, F.R.S. "Hereditary Genius." 1st edn. Macmillan, 1869.

(2) Francis Galton, F.R.S. "Natural Inheritance." Macmillan, 1889.

(3) Francis Galton, F.R.S. "The average contribution of each several ancestor to the total heritage of the offspring." (includes the work on Basset-hounds). Proc. Roy. Soc., Vol. 61, 1897.

(4) Professor Karl Pearson, F.R.S. "Regression, heredity, and panmixia." Phil. Trans. (A), Vol. 187, 1896.

(5) Professor Karl Pearson, F.R.S. "On the law of ancestral heredity." Proc. Roy. Soc., Vol. 62, 1898.

(6) Professor Karl Pearson. "Genetic Selection. Inheritance of fertility in man and of fecundity in thorough-bred racehorses." Phil. Trans. (A). Vol. 192, 1899.

(7) Professor Karl Pearson. "The Grammar of Science." 2nd edn., 1900.

(8) Professor Karl Pearson with L. Bramley-Moore. "On the inheritance of coat-colour in horses. On the inheritance of eye-colour in man." Phil. Trans. (A). Vol. 195, 1900.

(9) Professor Karl Pearson with Miss M. Beeton. "On the inheritance of duration of life and the intensity of natural selection in man." Biometrika, Vol. 1, October, 1901.

(10) Professor Karl Pearson. "On the fundamental conceptions of biology." Biometrika, Vol 1, April, 1902. [A reply to Mr. Bateson's (12)].

(11) Professor Karl Pearson. "On the influence of natural selection on the variability and correlation of organs." Phil. Trans. (A). Vol. 200, 1902.

(12) W. Bateson, F.R.S. "Heredity, differentiation, and other conceptions of biology." Proc. Roy. Soc., Vol. 69, 1901.

(13) E. Warren, D.Sc. "An observation on inheritance in parthenogenesis." Proc. Roy. Soc., Vol. 65, 1899.

(14) E. Warren, D.Sc. "Variation and inheritance in the Parthenogenetic generations of the Aphis *Hyalopterus Trirhodus* (Walker). Biometrika, Vol. 1, October, 1901.

(15) Professor W. F. R. Weldon, F.R.S. "On Mendel's Laws of alternative inheritance in peas." Biometrika Vol. 1, Jan., 1902.

A REVISION OF THE CLASSIFICATION OF THE GREEN ALGÆ

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(*concluded from page* 220.)

Fam. III. BOTRYDIACEAE.

Plant-body a well-developed *coenocyte, differentiated to form "root" and "shoot."* Chromatophores very numerous. *Gametes not observed.*

Genus.

Botrydium. Wallroth, 1815.

Plant a pyriform bladder of some size, growing on wet clay in which the tubular branched root-system ramifies. Pyrenoid-like bodies present in the very young stages, but they do not form starch. Reproduction by division of the contents to form numerous zoospores with two chromatophores and presumably two unequal flagella, and also by oval aplanospores which may develop to form new individuals or zoosporangia.

Series III. **Vaucheriales.**

Plant-body always *coenocytic.* Chromatophores numerous, parietal, discoid, yellowish and devoid of pyrenoids; *starch or oil* may be *the reserve material.* Asexual reproduction by zoospores, aplanospores or akinetes. *The simple swarmers possess two flagella* of about equal length, *one directed forwards and the other backwards.*

Fam. I. VAUCHERIACEAE.

Plant-body a branched tubular thallus, aquatic or terrestrial, and usually with 'root' branches. *Asexual reproduction by 'synzoospores',* aplanospores *or akinetes. Sexual reproduction by oogamy;* the oogonia arising by swelling of the ends of branches of the thallus, and containing a single egg-cell rich in chlorophyll, the antheridia arising similarly and containing numerous colourless antherozoids, with two opposed flagella, attached a little way from the apex of the antherozoid. *Reproductive regions always delimited by septa.*

Genera.

1. *Vaucheria.* De Candolle, 1803.

   The thallus never branches truly dichotomously. Oil is the assimilatory reserve product. Asexual reproduction by oval compound zoospores, containing a number of nuclei, and covered superficially with pairs of flagella, one pair to each nucleus.

2. *Dichotomosiphon.* Ernst, 1902.

   The thallus branches dichotomously. Starch is the assimilatory reserve product. Asexual reproduction by swollen segments of the thallus (akinetes) which, after resting, give rise to new branches. No zoospores observed.

Fam. II. PHYLLOSIPHONACEAE.

Plant-body endophytic and more or less *parasitic. Reproduction only by* the formation of numerous *aplanospores,* which are expelled by swelling of the inner layer of the thallus wall. *No septa formed to limit the reproductive region.* No sexual reproduction.

1. *Phyllosiphon.* Just, 1882.

   Thallus a much-branched tube parasitic in leaves. Both oil and starch grains occur.

2. *Phytophysa.* Weber van Bosse, 1890.

   Thallus globular, parasitic in the cortex of stems of higher plants. Oil and cellulose (?) grains occur. In reproduction, the peripheral protoplasm forms aplanospores, while the central part forms a cellulose "kernel," between which and the swelling thallus wal the spores become squeezed, and are finally expelled by rupture of the wall.

NOTE.—It was originally our intention to include in this revision, the Glaucophyceae (cf. Introduction p. 19), but further consideration of the forms included by Bohlin under this name has led us to the conclusion that they are too remote from the four classes just considered to be dealt with here, and that their real affinities are probably with quite other groups of Algæ.

ADDENDA.

VERY soon after commencing the publication of this system of classification, we decided that it would be more convenient to include diagnoses of all sufficiently known genera, and not, as indicated in the Introduction, of the more important ones only. This scheme has been carried out thence-forward to the best of our knowledge; though no doubt a few adequately known genera have been overlooked. The following omissions have been noticed during the progress of the work.

Brachiomonas. Bohlin, 1897. To follow *Chlamydomonas*, p. 23.

Body pointed behind and produced into four lateral processes anteriorly. First vegetative division longitudinal. Planogametes of the same form as the vegetative cells, but of varying sizes and tending to conjugate anisogamously.

Chroolepus. Karsten, not Agardh, 1891. To follow *Trentepohlia*, p. 166.

Thallus consisting of an epiphytic irregular disc, one cell thick, which produces also upright free branches of some length (resembling *Trentepohlia.*) Zoosporangia may be formed on either the disc or the upright branches.

Dictyocystis. Lagerheim, 1890. To follow *Dictyosphaerium*, p. 71.

Like *Dictyosphaerium*, but chromatophore radiating from a central pyrenoid.

Elakatothrix. Wille, 1895. To follow *Actinastrum*, p. 91.

Cells spindle-shaped, arranged in a longitudinal series, and surrounded by a mucilaginous sheath. Chromatophore parietal containing a large pyrenoid and covering the whole cell-wall except at the ends. Cell-division only in the transverse direction.

Ichthyocercus. West and G. S. West, 1897. To follow *Tetmemorus*, p. 191.

Like *Tetmemorus*, but terminal furrows broad and shallow, and a short spine on each of the four angles of the cell.

Lauterborniella. Schmidle, 1900. To follow *Crucigenia*, p. 91.

Cells united by mucilage to form four-celled cœnobia; seen from the edge of the cœnobium each cell is semilunar and has two diverging horns. Chromatophore parietal with a single pyrenoid. Daughter-cœnobia arise by two crossing radial divisions of each cell.

Pleurothamnion. Borzi, 1895. To follow *Gongrosira*, p. 165.

Closely resembles *Gongrosira*, but the zoosporangia arise in groups as a result of division of vegetative cells, and each contains only four to eight zoospores.

Roya. West and G. S. West, 1896. To follow *Closterium*, p. 190.

Differs from *Closterium* by the cells not tapering at the ends, by the absence of terminal vacuoles, and by the position of the nucleus close to the lateral wall.

Sphærocystis. Chodat, 1897. To precede *Palmodactylon*, p. 72.

Colonies spherical, the cells varying in number from one to several hundred. Multiplication by division of the cells to form different daughter-colonies, and also by zoospores.

Tetrasporidium. Moebius, 1893. To follow *Tetraspora*, p. 69.

Thallus a floating, spongy, mucilaginous colony, with numerous irregular perforations and processes produced by unequal distribution of cell division; Reproduction by swarmers, formed from only part of the protoplasm of the mother cell, and leaving a periplast behind. Flagella not observed.

BIBLIOGRAPHY

containing references to the genera published since the appearance of Wille's "Conjugatae" and "Chlorophyceae" (1890) in Engler and Prantl's "Natürlichen Pflanzenfamilien."

A few references to fundamental work published since 1890 on genera of prior date are given in square brackets.

Acanthosphæra. Lemmermann, Forschungsberichte der Biolog. Stat. zu Plön, 1899, Teil 7, p. 118, Taf. I, figs 10 and 11.

[*Aphanochaete* (reproduction of). Huber, Bull. Soc. Bot. France, 1894, Tome xli, p. xciv, pl. vii.]

Askenasyella. Schmidle, Hedwigia, 1902., Bd. xli., p. 154., Fig. B, 1-3.

Bohlinia. Lemmermann, Forschungsberichte der Biolog. Stat. zu Plön, 1899, Teil 7, p. 120.

Brachiomonas. Bohlin, Öfvers. K.Vet. Akad. Förhandl., 1897, p. 508, figs. 1-3.

Bumilleria. Borzi, Studi Algologici, Fasc. ii., Palermo, 1895, p. 185, Tav. xvi., xvii. See also Wille, p. 85, fig. 49.

Catena. Chodat, Mémoires de l'Herbier Boissier, No. 17, 1900, p. 9, fig. 13.

Centratractus. Lemmermann, Ber. d. Deutsch. Bot. Ges. 1900, Bd. xviii., p. 274.

Chaetosiphon. Huber, Ann. sci. nat., Bot., 1892, Ser. vii., Tome 16, p. 338, pl. xviii.

Chaetosphaeridium. Klebahn, Jahrb. f. wiss., Bot. 1892, Bd. xxiv., p. 268, Taf. iv.

Chalmasia. Solms-Laubach, Trans. Linn. Soc., Bot., 1895, Ser. II., Vol. 5, p. 32.

Characiopsis. Borzi, Studi Algologici, Fasc. ii., Palermo, 1895, p. 150. Tav. xiv.

Chlamydoblepharis. Francé, Jahrb. f. wiss. Bot. 1894, Bd. 26, p. 362. Text-fig. 9, and Taf. xvii., xviii.

Chloramœba. Bohlin, Öfvers. K.Vet. Akad Förhandl., 1897, p. 513, fig. 6.

Chlorobotrys. Bohlin, Bihang till K. Svenska Vet.-Akad. Handlingar, 1901. Bd. 27, Afd. iii., No. 4, p. 34, fig. 9.

Chlorosaccus. Luther, Bihang till K. Svenska Vet.-Akad. Handlingar, 1899, Bd. 24, Afd. iii., No. 13, mit ein Tafel.

Chodatella. Lemmermann, Hedwigia, 1898, Bd. 37, p. 309. Taf. x. figs 10-18.

Chroolepus. Karsten, Ann. Jard. Bot. Buitenzorg, 1891, Tome x., p. 22. Pl. iv.

Coccomyxa. Schmidle, Ber. d. Deutsch. Bot. Ges., 1901. Bd. xix., p. 20. Taf. x. Figs. 6-25.

[*Conferva* (reproduction of). Scherffel, Bot. Zeit., 1901. Abt. i., p. 149.]

Conochaete. Klebahn, Jahrb. f. wiss. Bot, 1893. Bd. xxv., p. 310, Taf. xiv.

Crucigeniella. Lemmermann, Ber. d. Deutsch. Bot. Ges. 1900. Bd. xviii., p. 307.

Dichotomosiphon. Ernst, Beihefte zum Bot. Centralblatt, 1902, Bd. xiii, Heft I, p. 113, Taf. vi-x.

Dicoleon. Klebahn, Jahrb. f. wiss. Bot., 1893, Bd. xxv, p. 307, Taf. xiv.

Echallocystis. Bohlin, Bihang till K. Svenska Vet.-Akad. Handlingar, 1897, Bd. 23, Afd. iii., No. 7, p. 7, Taf. i.

Elakatothrix. Wille, Biolog. Centralblatt, 1898, Bd. xviii., p. 302.

Euastropsis. Lagerheim, Tromso Museums Aarshefter, 1894, No. 17. Figs. 8-27.

Eudorinella. Lemmermann, Ber. d. Deutsch. Bot. Ges. 1900, Bd. xviii., p. 307.

Excentrosphaera. Moore, Botanical Gazette, 1901, Vol. 32. p. 320. Pl. xii. figs. 21-27.

Foreliella. Chodat, Bull. de l'Herbier Boissier, 1898, Vol. vi. p. 434.
Franceia. Lemmermann, Hedwigia, 1898, Bd. 37, p. 307.

Gloeoplax. Schmidle, Hedwigia, 1899, Bd. xxxviii., p. 159, Taf. vi.
Golenkinia. Chodat, Journal de Botanique, 1894, Tome viii., p. 305, Pl. iii, figs. 1-30.
Gonatoblaste. Huber, Ann. sci. nat., bot., 1892, Ser. vii, T. 16, p. 311. Pl. ix.

Hofmania. Chodat, Mémoires de l'Herbier Boissier, 1900. 17, pp. 8, 9. Figs. 10, 11.

Ichthyocercus. West and G. S. West, Journal of Botany, 1897, vol. 35, p. 80. Tab. 368. Figs. 26-31.
Ineffigiata. West and G. S. West, Journal Roy. Micr. Soc., 1897 p. 503.

Kirchneriella. Schmidle, Ber. d. Naturf. Gesell. in Freiburg, 1893, Bd. vii, p. 82, Pl. [II] III, figs. 1-3.

Lagerheimia. Chodat, La Nuova Notarisia, 1895, p. 87. Figs. 1-12.
Lauterborniella. Schmidle, Ber. d. Deutsch. Bot. Ges., 1900, Bd. xviii., p. 149, Taf. vi, Figs. 2, 3.
Lemmermannia. Chodat, Mém. de l'Herb. Boiss., 1900, 17, pp. 3-6., figs. 1-8.

Mougeotiopsis. Palla, Ber. d. Deutsch. Bot. Ges., 1894, Bd. xii., p. 228. Taf. xviii.
Myxochaete. Bohlin, Bihang till Svenska Vet-Akad. Handlingar, 1890, Bd. 15, Afd. iii., No. 4. See Wille "Nachträge" to Chlorophyceae, p. 160.

Nordstedtia. Borzi, La Nuova Notarisia, Ser. III, 1892, p. 50.

Oedocladium. Stahl, Jahrb. f. wiss. Bot., 1891, Bd. 23, p. 339, Taf. xvi., xvii.
[*Oocardium.* Senn, Bot. Zeit., 1899, Abt. i, p. 81, Text-figs. 31–39. Taf. iii. Figs. 13-27.]
Oodesmus. Schmidle, Hedwigia, 1902, Bd. xli., p. 162, fig. B, 4.

Phythelios. Frenzel, Archiv f. Mikr., Anat. 1891, Bd. 38, p. 14, Taf. I., fig. 6. See also Penard, Bull de l' Herb. Boiss., 1901, p. 677.
Phytophysa. Weber van Bosse, Ann. Jard. Bot. Buitenzorg, 1890, Tome v. See Wille, "Nachträge" to Chlorophyceae, p. 160.
Pilidiocystis. Bohlin, Bihang till K. Svenska Vet.-Akad. Handlingar, 1897, Bd. 23, Afd. iii, No. 7, p. 15, Taf. I.
Platydorina. Kofoid, Bull. Illinois State Lab. Nat. Hist., 1899, Vol. v., p. 419, Pl. xxxviii., figs. 1-5. Reprinted in Ann. and Mag. Nat. Hist., 1900., Ser. 7., Vol. vi. p. 541, pl. vii.
Pleodorina. Shaw, Bot. Gazette, 1894, vol. 19, p. 279, pl. xxvii., figs. 1-9.

[*P. illinoisensis* Kofoid, Bull. Illinois State Lab. Nat. Hist., 1898, Vol. v., p. 27. Pl. xxxvi. and xxxvii. Reprinted in Ann. and Mag. Nat. Hist., 1900, Ser. 7, Vol. vi, p. 139 Pl. v. and vi.]

Pleurodiscus. Lagerheim, Videnskabs-Selskabets Skrifter. Math-naturv. Klasse, 1895, No. 5, fig. 1.

Pleurothamnion. Borzi, Studi Algologici, Fasc. ii., Palermo 1895, p. 318, Pls. xxvii and xxvii.

Polychloris. Borzi, La Nuova Notarisia, 1892, p. 51.

[*Polytoma.* Francé, Jahrb. f. wiss. Bot. 1894, Bd. 26. p. 295.]

Prasinocladus. Kuckuck, Wiss. Meeresuntersuchungen, Kiel, N.F., 1896, Bd. I, Heft. I, p. 261, fig. 28

Protosiphon. Klebs, Die Bedingungen der Fortpflanzung bei einigen Algen und Pilzen, 1896, p. 169, Taf. I.

Pseudocodium. Weber van Bosse, Journ. Linn. Soc., Bot., 1896, Vol. xxxii., p. 209, pl I., figs. 1-9.

Pseudendoclonium. Wille, Videnskabs Selskabets Skrifter, Math-naturv. Klasse, Christiania, 1900. No. 6, p. 29, Taf. iii.

Pyxispora. West and G. S. West, Journal of Botany, 1897, Vol. 35, p. 39, Pl.370, figs. 3-4.

Radiofilum. Schmidle, Flora 1894, p. 47, pl. vii.

Richteriella. Lemmermann, Hedwigia, 1898, Bd. 37, p. 305, Taf. X. Figs. 1–7.

Roya. West and G. S. West, Journ. Roy. Micr. Soc., 1896, p. 152. Pl. iii. Figs. 23-24.

Schroederia. Lemmermann, Hedwigia, 1898, Bd. 37, p. 311.

Selenoderma. Bohlin, Bihang till K. Svenska Vet-Akad. Handlingar, 1897, Bd. 23, Afd. iii, No. 7, p. 21. Taf. i.

Sphærocystis. Chodat, Bull. de l'Herbier Boissier, 1897. Tome, v., pp. 119 and 292, Pl. 9, figs. 1-13.

Stapfia. Chodat, Bull. de l'Herbier Boissier, 1897. Tome v., p. 939. Pl. xxiii.

Stipitococcus. West and G. S. West, Alga-Flora of Yorkshire, 1901. p. 127.

Temnogametum. West and G. S. West, Journal of Botany, 1897. Vol. 35, p. 37. Tab. 370, figs. 5-9.

Tetracoccus. West, Journal Roy. Micr. Soc., 1892, p. 735, pl. x.

Tetragonium. West and G. S. West. Journal Roy. Micr. Soc., 1896, p. 160, pl. iii., figs. 1-13.

Tetrasporidium. Möbius, Ber. d. Deutsch. Bot. Ges., 1893, Bd. xi., p. 122, Taf. viii.

Tetrastrum. Chodat, Bull. de l'Herbier Boissier, 1895., Tome iii., pp. 113 and 114.

Willea. Schmidle, Ber. d. Deutsch. Bot. Ges., 1900, Bd. xviii., p. 157.

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